# ARJ

## Defense Acquisition Research Journal

# Learning from the PAST

*Cost Overrun Optimism: Fact or Fiction?*
**Maj David D. Christensen, USAF**

*Systemic Fiscal Optimism in Defense Planning*
**Leland G. Jordan**

*Resilience—A Concept*
**Col Dennis J. Rensel, USAF (Ret.)**

*Performance Indexing: Assessing the
Nonmonetized Returns on Investment in
Military Equipment*
**Ian D. MacLeod and
Capt Robert A. Dinwoodie, USMC**

**The Defense Acquisition Professional Reading List**
*The Dream Machine: The Untold History of the
Notorious V-22 Osprey*
**Written by Richard Whittle**
**Reviewed by Dr. Owen Gadeken**

# Article List

# ARJ Extra

# Defense Acquisition Research Journal

## A Publication of the Defense Acquisition University

**Defense Acquisition University**

# Defense Acquisition Research Journal

A Publication of the Defense Acquisition University

# CONTENTS | Featured Research

# CONTENTS | Featured Research

# CALL FOR AUTHORS

We are currently soliciting articles and subject matter experts for the 2015–2016 *Defense Acquisition Research Journal* (*ARJ*) print years. Please see our guidelines for contributors for submission deadlines.

Even if your agency does not require you to publish, consider these career-enhancing possibilities:

- Share your acquisition research results with the Acquisition, Technology, and Logistics (AT&L) community.
- Change the way Department of Defense (DoD) does business.
- Help others avoid pitfalls with lessons learned or best practices from your project or program.
- Teach others with a step-by-step tutorial on a process or approach.
- Share new information that your program has uncovered or discovered through the implementation of new initiatives.
- Condense your graduate project into something beneficial to acquisition professionals.

## ENJOY THESE BENEFITS:

- Earn 25 continuous learning points for publishing in a refereed journal.
- Get promoted or rewarded.
- Become part of a focus group sharing similar interests.
- Become a nationally recognized expert in your field or speciality.
- Be asked to speak at a conference or symposium.

We welcome submissions from anyone involved with or interested in the defense acquisition process—the conceptualization, initiation, design, testing, contracting, production, deployment, logistics support, modification, and disposal of weapons and other systems, supplies, or services (including construction) needed by the DoD, or intended for use to support military missions.

*If you are interested, contact the* Defense ARJ *managing editor (**DefenseARJ@dau.mil**) and provide contact information and a brief description of your article. Please visit the* Defense ARJ *Guidelines for Contributors at* **http://www.dau.mil/pubscats/Pages/ARJ.aspx**.

# 2016 HIRSCH RESEARCH PAPER COMPETITION

## CALL FOR PAPERS

Research topics may include:
- Improve Professionalism of the Total Acquisition Workforce
- Career Path and Incentives
- Agile Program Management
- Incorporating Foreign Military Sales and Direct Contractor Sales Strategies into Programs
- Controlling Costs Throughout the Product Lifecycle
- System Cyber Hardness

## GROUND RULES

- The competition is open to anyone interested in the DoD acquisition system and is not limited to government or contractor personnel.

- Employees of the federal government (including military personnel) are encouraged to compete and are eligible for cash awards unless the paper was researched or written as part of the employee's official duties or was done on government time. If the research effort is performed as part of official duties or on government time, the employee is eligible for a non-cash prize, i.e., certificate and donation of cash prize to a Combined Federal Campaign registered charity of winner's choice.

- First prize is $1,000. Second prize is $500.

- The format of the paper must be in accordance with guidelines for articles submitted for the *Defense Acquisition Research Journal*.

- Papers are to be submitted to the DAU Director of Research: research@dau.mil.

- Papers will be evaluated by a panel selected by the DAUAA Board of Directors and the DAU Director of Research.

- Award winners will present their papers at the DAU Acquisition Community Training Symposium, Tuesday, April 12, 2016, at the DAU Fort Belvoir campus.

- Papers must be submitted by December 16, 2015, and awards will be announced in January 2016.

# FROM THE CHAIRMAN AND EXECUTIVE EDITOR

Dr. Larrie D. Ferreiro



The theme for this edition of *Defense Acquisition Research Journal* is "Learning from the Past." As Under Secretary of Defense for Acquisition, Technology, and Logistics Frank Kendall noted in 2011, the Better Buying Power initiatives were not so much a collection of novel ideas as they were guidelines "distilled from best practices and lessons learned."[1] He also reminded the acquisition workforce in his rollout of the revised DoD Instruction 5000.02 in January 2015, that "we will never stop learning from our experience."[2]

This issue begins with a rarely seen feature in the pages of *Defense ARJ*—Letters to the Editor. We often receive comments about the articles published in this *Journal*, but rarely are we afforded the opportunity to publish them. In this issue we present a reader's comments, and the authors' subsequent reply, to an article from the July 2013 issue, "Current Barriers to Successful Implementation of FIST Principles." We appreciate and encourage this level of open discourse on topics of immediate interest to the Defense Acquisition Workforce.

In keeping with the theme of learning from the past, the first two articles are reprints from previous issues, but which continue to have relevance today. In "Cost Overrun Optimism: Fact or Fiction?" by Maj David D. Christensen, USAF, (originally published in 1994), and Leland G. Jordan's "Systemic Fiscal Optimism in Defense Planning" (published in 2000), the authors identified systematic underestimating of cost growth and systematic overestimating of resource availability as major contributing factors to inaccurate and unrealistic cost estimates. This dilemma is not limited to defense programs, but exists in any complex system acquisition; in the book *Megaprojects and Risk: An Anatomy of Ambition* by Brent Flyvbjerg et al., reviewed in *Defense ARJ* (Issue No. 59, July 2011, p. 336), which examines three large European civil engineering programs, the authors cite "overoptimistic estimates" as being primary causes for cost and schedule overruns.

Col Dennis J. Rensel, USAF (Ret.), in "Resilience—A Concept," takes a holistic approach to measuring the "health" of systems and capabilities. In "Performance Indexing: Assessing the Nonmonetized Returns on Investment in Military Equipment," the authors Ian D. MacLeod and Capt Robert A. Dinwoodie, USMC, tackle the problem of calculating the "worth" of investments in military equipment programs when a direct comparison using monetary returns falls short.

The featured book in this issue's Defense Acquisition Professional Reading List is Richard Whittle's *The Dream Machine: The Untold History of the Notorious V-22 Osprey*, reviewed by Defense Acquisition University Professor Owen Gadeken.

---

[1] Kendall, F. (2011, September-October). Better buying power: Foreword. *Defense AT&L Magazine, 40*(5), 2–4.

[2] Kendall, F. (2015, January 7). Department of Defense Instruction 5000.02 [Memorandum]. Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology & Logistics.

# LETTERS TO THE EDITOR

## From the Executive Editor, *Defense ARJ*

We often receive comments about the articles published in the *Defense ARJ*, but rarely have we been afforded the opportunity to publish them. In July 2013 we published the article "Current Barriers to Successful Implementation of FIST Principles" by Brandon Keller and J. Robert Wirthlin (abstract and link below). We received critiques from Dan Ward, one of the sources that the authors cite in their article. After contacting the authors, we offered to publish Lt Col Ward's critique along with a response from the original authors. Both parties agreed, and their letters are presented here.

## Current Barriers to Successful Implementation of FIST Principles

Capt Brandon Keller, USAF, and Lt Col J. Robert Wirthlin, USAF
*Defense ARJ*, July 2013, Vol. 20 No. 2: 194–217
http://www.dau.mil/publications/DefenseARJ/ARJ/ARJ66/ARJ_66-Keller.pdf

Abstract: The Fast, Inexpensive, Simple, and Tiny (FIST) framework proposes a broad set of organizational values, but provides limited guidance on practical implementation. Implementing FIST principles requires clarifying the definitions of "fast," "inexpensive," and "simple," recognizing where FIST does and does not apply. Additionally, a subset of the FIST heuristics was expanded upon to increase their usefulness for practitioners. The primary research findings are that FIST principles are less conducive for highly complex or novel systems, immature technologies, future needs, acquisitions in early development phases, or when performance is the foremost value. FIST principles were also found to be constrained by the acquisition process, the requirements process, and oversight.

**Letter from Lt Col Dan Ward, USAF**

To The Editor,

There are three significant misrepresentations in the 2013 article "Current Barriers to Successful Implementation of FIST Principles," by Keller and Wirthlin. I would like to offer the following corrections:

1.  The authors misrepresent my opinion several times, saying "Ward agrees" to propositions I disagree with. Specifically, the authors claim I believe FIST is "not conducive for immature technologies" and that using mature technologies "is often the antithesis of innovation." This demonstrates a shallow reading of the FIST literature and a misunderstanding of the nature of innovation itself. Many writers, including myself, explain that innovation often results from putting mature technologies together in new and interesting ways. Using mature components is therefore entirely consistent with delivering innovative new capabilities to the marketplace.

2.  The authors misrepresent the scope of their own research. They claim to have reviewed "the multitude of materials related to FIST," but the most recent document they cited was published in 2009. They therefore omitted four years of publications on the topic, upwards of 25 articles, journal papers, conference presentations, and other material published by myself and others. Such shallow research presents an incomplete picture of the topic and does a disservice to readers. It also helps explain why their portrayal of FIST was so far off the mark and why they claimed "no evidence is offered" and that FIST "provides limited guidance on practical implementation." A more complete survey of the recent literature would have revealed considerable evidence and guidance.

3.  Finally, the authors misrepresent their contribution to the FIST concept. They claim to have "expanded upon" the FIST heuristics and offered some "recommended additions," but fully half of their additions either cite my work, lightly paraphrase my work without citation, or are copied word-for-word from my work without citation. For example, one of the heuristics they claimed to add was the following: "The project leader's influence over the development is inversely proportional to the budget and schedule." That exact line appears on page 103 of my thesis, but the authors present it as their own original contribution.

The article is riddled with other errors, largely resulting from shallow research (see #2 above). It attributes the concept of "disruptive innovation" to a 2011 publication by Dyer instead of a 1995 paper by Christensen. It asserts "early operator feedback on a satellite program… is nearly impossible," which overlooks the successful Operationally Responsive Space office, established in 2007. It claims "FIST is less conducive for complex, large programs," which overlooks the FIST Navy's Virginia Class submarine program.

While I enthusiastically welcome discussions and debates about FIST, I am disappointed in the way Keller and Wirthlin misrepresented my opinions, my work, and their own contribution to the topic. They incorrectly attributed opinions to me which I do not share, overlooked four years' worth of material, and claimed my words as their own. I hope future writers do not follow their example and instead present a more accurate, thorough, and original contribution.

### Response from Capt Brandon Keller, USAF, and Lt Col J. Robert Wirthlin, USAF

To the Editor,

We appreciate *Defense ARJ* giving us the opportunity to respond to Lt Col Ward's Letter to the Editor about our article in the July 2013 *Defense ARJ* edition. We have a professional disagreement with aspects of FIST that we documented in this peer-reviewed forum and still assert to be true. Our response to his remarks follows:

1.  We never wrote that Ward agrees that FIST is not conducive for immature technologies… we say that Ward agrees "that a key to FIST implementation is the use of mature technologies" (Ward, 2009). The finding "FIST is not conducive for immature technologies" is our conclusion; however, although Ward says he disagrees with the statement, pp. 16, 17, 32, 44, 89, and 90 of Ward's thesis from 2009 clearly promote the use of mature technology in FIST.

    We also agree combining mature technology in novel ways can produce innovative results.

2.  We did not misrepresent anything. The most recent cited document in our published work was from 2012, but there are several reasons the most recent FIST-related citation was 2009:

    a.   We focused on citing peer-reviewed publications for academic rigor; and,

    b.   We tried to cite the original document in which a viewpoint was presented—many newer publications merely re-stated previously documented FIST viewpoints. Quantity of citations about FIST does not strengthen the veracity of the assertions.

    c.   Concern over whether we did not attribute conclusions by other authors from earlier dates should not imply we were unaware of those authors' conclusions, nor does it demonstrate academic malpractice. Researchers in similar fields often draw the same conclusions independently.

3.   We did miss one citation. In August 2013, we privately apologized for the oversight of the heuristic; it was an honest oversight on our part and in no way intended to imply his work as ours.

There are clear distinctions between FIST and our own conclusions, and we disagree that half of the heuristics come from Ward's body of work. The heuristics in our article that do come from others' work (and cited as such) are included because we believe they further solidify our own positions. This also includes heuristics cited from Ward that add credence to our findings.

It is unfortunate that Ward uses a strawman of embellished assertions designed to discredit our work without directly confronting the conclusions or presenting any evidence that would further enlighten discussion and knowledge of the subject matter. Rigorous academic research ought to question and test the assertions of the author. Our work invites other researchers to join the discussion. FIST concepts have been around a very long time in the project management profession, but citing a handful of successful programs doesn't show causality of success when compared to the thousands of unsuccessful programs. It is far more the norm for the current barriers to FIST implementation to surface than FIST principles leading to a successful program by itself. We still assert that barriers exist to successful implementation of FIST in all types of defense acquisition scenarios.

# DAU CENTER FOR DEFENSE ACQUISITION RESEARCH

## RESEARCH AGENDA 2015

The Defense Acquisition Research Agenda is intended to make researchers aware of the topics that are, or should be, of particular concern to the broader defense acquisition community throughout the government, academic, and industrial sectors. The purpose of conducting research in these areas is to provide solid, empirically based findings to create a broad body of knowledge that can inform the development of policies, procedures, and processes in defense acquisition, and to help shape the thought leadership for the acquisition community.

Each issue of the *Defense ARJ* will include a different selection of research topics from the overall agenda, which is at: http://www.dau.mil/research/Pages/researchareas.aspx

### Measuring the Effects of Competition

- What means are there (or can be developed) to measure the effect on defense acquisition costs of maintaining an industrial base in various sectors?

- What means exist (or can be developed) of measuring the effect of utilizing defense industrial infrastructure for commercial manufacture in growth industries? In other words, can we measure the effect of using defense manufacturing to expand the buyer base?

- What means exist (or can be developed) to determine the degree of openness that exists in competitive awards?

- What are the different effects of the two best-value source-selection processes (tradeoff vs. lowest price technically acceptable) on program cost, schedule, and performance?

## Strategic Competition

- Is there evidence that competition between system portfolios is an effective means of controlling price and costs?

- Does lack of competition automatically mean higher prices? For example, is there evidence that sole source can result in lower overall administrative costs at both the government and industry levels, to the effect of lowering total costs?

- What are the long-term historical trends for competition guidance and practice in defense acquisition policies and practices?

- To what extent are contracts being awarded non-competitively by congressional mandate, for policy interest reasons? What is the effect on contract price and performance?

- What means are there (or can be developed) to determine the degree to which competitive program costs are negatively affected by laws and regulations such as the Berry Amendment and Buy American Act?

# Cost Overrun
## Optimism:
## FACT or
## FICTION?

*Maj David D. Christensen, USAF*

Program managers are advocates by necessity. When taken to the extreme, program advocacy can result in the suppression of adverse information about the status of a program. Such was the case in the Navy's A-12 program. In "A-12 Administrative Inquiry," Beach (1990) speculates that such "abiding cultural problems" were not unique to the Navy. To test that assertion, this article examines cost overrun data on 64 completed acquisition contracts extracted from the Defense Acquisition Executive Summary database. Cost overruns at various contract completion points are compared with projected final cost overruns estimated by contractor and government personnel. The comparison shows that the overruns projected by the contractor and government were excessively optimistic throughout the lives of the contracts examined. These results were found insensitive to contract type (cost, price), contract phase (development, production), the type of weapon system (air, ground, sea), and the military service (Air Force, Army, Navy) that managed the contract.

*Image designed by Diane Fleischer*

# Cost Overrun Optimism: Fact or Fiction?

According to Gansler (1989, p. 4), the average cost overrun on a major defense contract has been about 40 percent. Although some of the causes of cost overruns are beyond the control of program managers, supporting an unrealistically low estimate of the final cost of a defense contract can only harm the program in the long run. The cancellation of the Navy's A-12 program in January 1991 is a highly publicized example of this problem.

Chester P. Beach (1990), the Inquiry Officer of the A-12 cancellation, reported that pessimistic projections regarding the program's cost were suppressed to protect the program and the careers of key managers. When Secretary of Defense Dick Cheney canceled the program in January 1991, he complained that no one could tell him its final cost (Morrison, 1991). In fact, there were many estimates of the program's completion cost: some estimates were more than $1 billion higher than the ones supported by the government program office and by the contractors. The problem was the delayed and reluctant communication of the pessimistic estimates to key decision makers above the government program office. Although no one can say with certainty that the timely communication of more realistic estimates would have saved the A-12, it seems likely that at least part of the $1.35 billion in excess progress payments made to the contractors could have been avoided (Ferber & Math, 1991).

More realistic estimates and a culture that will tolerate them are needed. Program managers/directors are necessarily advocates of their programs. However, program advocacy is no excuse for suppressing critical information about a program's cost, schedule, or technical performance. In an acquisition policy letter, J. J. Welch (1991), Assistant Secretary of the Air Force (Acquisition), wrote:

> A program director (PD) must be an advocate of his or her program....The PD's advocacy must not cross the line into attempting to "sell" the program, but must clearly be viewed as supportive to the user's requirements. The PD must articulate the pros and cons, as well as the "maturity curve" status, in a clear and comprehensive manner to preclude unfulfilled expectations or surprises. Such advocacy must be based on honesty and integrity to accurately portray program status.[1]

Regardless of this policy statement, Gansler (1989, p. 212) reports that the majority of program managers' time is spent "selling" their programs to budget committees. In addition, research has shown that, once a program is more than 15 percent to 20 percent complete, it is highly unlikely that the final cost overrun will be less than the present cost overrun (W. Abba, personal communication, 1992; Christensen & Payne, 1992; Heise, 1991; Wilson, 1991). Despite these facts, contractor and government program managers often claim optimistically that dramatic recoveries from cost overruns are possible.

Using information extracted from the Defense Acquisition Executive Summary (DAES) database, this article documents the optimistic forecasts of contract completion costs on 64 completed contracts. Average cost overruns at various contract completion points are compared with projected final cost overruns estimated by contractor and government personnel. The comparison shows that the overruns projected by the contractor and government were exceedingly optimistic throughout the lives of the contracts examined. These results were found insensitive to contract type (cost, price), contract phase (development, production), the type of weapon system (air, ground, sea), or the military service that managed the contract.
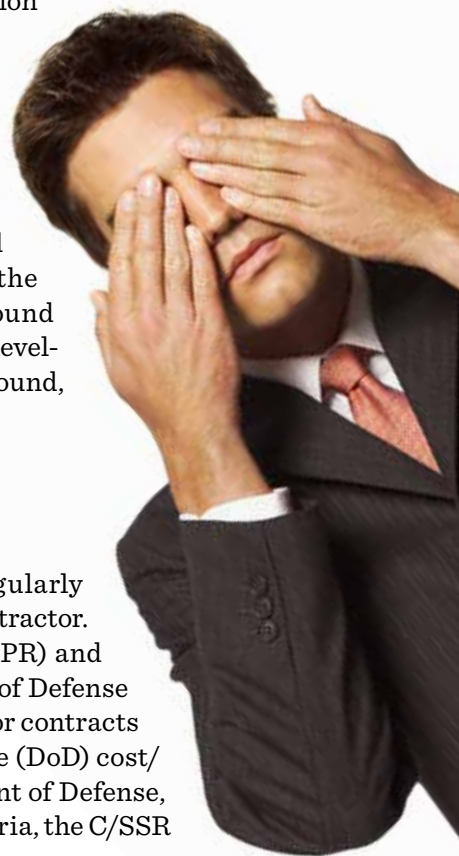
# Background

Cost overruns and projected final overruns are regularly reported on cost management reports prepared by the contractor. These reports include the Cost Performance Report (CPR) and the Cost/Schedule Status Report (C/SSR). Department of Defense Instruction 5000.2 stipulates that a CPR be submitted for contracts that require compliance with the Department of Defense (DoD) cost/schedule control systems criteria (C/SCSC) (Department of Defense, 1991). For contracts not required to comply with the criteria, the C/SSR is usually required.[2]

Cost/schedule control systems criteria are not a management system. Instead, they establish minimal standards for the management control systems used by the contractor and have two objectives:

1. For contractors to use effective internal cost and schedule management control systems; and

2. For the government to be able to rely on timely and auditable data produced by those systems for determining product-oriented contract status (Department of the Air Force, 1989).

Implicit in these objectives is the assumption that, if the contractor's management control systems comply with the criteria, the data generated by those systems are reliable (Christensen, 1989).

Data summarizing a contract's cost and schedule performance are listed in the cost-management report. Key data elements of the report are shown in Figure 1. The budgeted cost of work scheduled (BCWS) is the sum of budgets allocated to time-phased elements of work on the contract, known as work packages and planning packages. The cumulative expression of these budgets, the performance measurement baseline, takes on a characteristic S-shaped curve. The end point of the baseline, the budget at completion (BAC), represents the total budget of all the identified work on the contract.

As shown in the figure, the contractor also reports an estimate of the final cost of the contract, termed the estimate at completion (EAC). The EAC is an extrapolation of the cumulative actual cost of work performed (ACWP) to the end of the contract. If the projected final cost differs from the total budget, the contractor is predicting a cost overrun at completion. It is often revealing to compare the predicted cost overrun at completion to the present cost overrun. If the present overrun is worse than the predicted final overrun, the contractor is predicting effectively that the cost of the remaining work on the contract will be less than budgeted. For this article, the present cost overrun is defined as the difference between the cumulative budgeted cost for work performed (BCWP) and the cumulative ACWP (see Figure 1). The BCWP is the same number as BCWS, but is recorded when work is actually accomplished. Clearly, if the cost of the completed work exceeds the budget, a cost overrun is identified. If the cost overrun is significant, it is investigated to determine the cause. Hopefully, the timely and disciplined analysis of significant overruns will result in corrective action before the problems become serious.

The effectiveness of variance analysis depends on organizational culture. In a healthy culture a variance is considered an opportunity for improvement. In an unhealthy culture a variance is bad news, and individuals or

even organizations responsible for unfavorable variances may be punished. The result of this "shoot the messenger" culture can be the suppression of adverse information about a contract's status.

Although routine analysis in the A-12 program revealed adverse trends, the significance of the unfavorable cost and schedule variances was not revealed to senior civilian decision makers above the government program office. According to Beach (1990), the projected final completion costs supported by the contractor and the government program manager were unrealistic. For example, at the 37 percent completion point, the A-12 contractors reported a cost overrun of $459 million and a projected cost overrun at completion of $354 million (Campbell & Fleming, 1991).



FIGURE 1. ADVERSE COST VARIANCE, TERMED COST OVERRUN
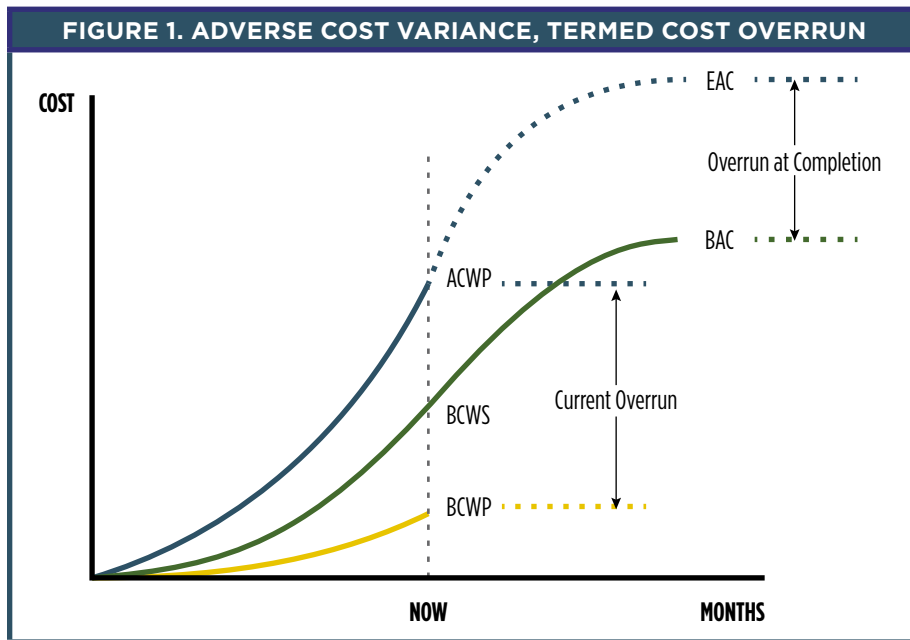
The government program manager's estimated final overrun was slightly higher than the contractor estimate yet less than the overrun to date.

Apparently the need to present an optimistic picture was a dominant consideration that effectively suppressed more realistic estimates. Near the end of his report, Beach (1990) speculates that this "abiding cultural problem" was not specific to the A-12, but was a problem common to other major defense programs:

There is no reason to believe that the factors which made these officials respond the way they did was unique to this military department. Indeed, experience suggests that they are not. Unless means can be found to solve this abiding cultural problem, the failures evidenced in this report can be anticipated to occur again in the same or a similar manner. (p. 27)

This article provides evidence that supports this assertion by examining available cost data on completed contracts.

# Methodology

The purpose of this study was to determine if the overruns at completion projected by contractor and government personnel are unrealistically optimistic. Research has established that, once a contract is 15 percent complete, the final cost overrun will exceed the cost overrun to date (W. Abba, personal communication, 1992; Christensen, 1989; Heise, 1991; Wilson, 1991). Thus, a projected overrun at completion is defined as unrealistically optimistic if it is less than the present cost overrun.

To test the hypothesis, averages of the present cost overrun, the projected cost overrun at completion, and the final cost overrun were computed from a sample of 64 completed contracts extracted from the DAES database (Department of Defense, 1991). This database contains contractor cost and schedule performance data on more than 500 defense contracts summarized quarterly by government program offices since 1970 (Christle, 1981). Because most of the contracts in this database are C/SCSC-compliant, the data are considered reliable.

Although the sampling technique was purely judgmental, the number and variety of contracts are considered sufficiently large to be general in nature. The period of performance for these contracts ranged from 1971 to 1991. Table 1 lists descriptive statistics on the average final cost overruns in the sample. For sensitivity analysis, the sample was divided into several categories, including contract type (price, cost), contract phase (development, production), the type of weapon system (air, ground, sea), and the Service managing the contract. For each category in the table, the number of contracts and the average, maximum, and minimum values for the final overrun are listed.

| TABLE 1. FINAL COST OVERRUN ON 64 CONTRACTS | | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Percent OF BUDGET** | | | | **$ MILLIONS** | | |
| **Category** | **Number** | **Avg** | **Min** | **Max** | **Avg** | **Min** | **Max** |
| Fixed Price | 41 | 20 | -3 | 109 | 34 | -3 | 407 |
| Cost | 23 | 14 | -1 | 46 | 41 | -2 | 493 |
| Development | 25 | 21 | -1 | 109 | 38 | -2 | 407 |
| Production | 39 | 16 | -3 | 46 | 35 | -3 | 493 |
| Air | 43 | 18 | -3 | 109 | 45 | -3 | 492 |
| Ground | 13 | 21 | 5 | 45 | 23 | 7 | 42 |
| Sea | 8 | 12 | O | 38 | 12 | O | 36 |
| Air Force | 18 | 19 | -1 | 109 | 49 | -2 | 407 |
| Army | 28 | 20 | -3 | 46 | 21 | -3 | 46 |
| Navy | 18 | 13 | O | 46 | 47 | O | 493 |
| **ALL** | **64** | **18** | **-3** | **109** | **36** | **-3** | **493** |

Equations 1, 2, and 3 define the current cost overrun, the projected cost overrun at completion, and final cost overrun. Of the three overruns, only the projected cost overrun at completion is an estimate, showing the difference between the budget and the estimated completion cost. The others are simply the difference between the budget and actual cost of the work.

*Current overrun (CO) = Cumulative (Cum) BCWP - Cum ACWP*    (1)

*Overrun at completion (OAC) = Contract budget base (CBB) - EAC*   (2)

*Final overrun (FO) = CBB - Final ACWP*          (3)

To normalize the data, the overruns were converted into percentages using Equations 4, 5, and 6. For the current cost overrun percentage, the cumulative BCWP was used. For the others, the CBB was used. The CBB is defined as the budget for all authorized work on a contract and includes the management reserve budget.

*Current overrun percentage = lOO\*(CO/Cum BCWP)*          (4)

*Overrun at completion percentage = lOO\*(OAC/CBB)*         (5)

*Final overrun percentage = lOO\*(FO/CBB)*             (6)

Each type of overrun (current, at completion, and final) was averaged for each category by dividing the number of contracts in that category into the total overrun for that category. The averaging was done at various stages of completion ranging from 10 to 100 percent completed (Equation 7).

$$Percentage\ completed = lOO*(Cum\ BCWP/CBB) \hspace{2cm} (7)$$

Data earlier than the 10 percent completion point were not considered sufficiently reliable. It can take as long as 1 year from contract award for the contractor to demonstrate C/SCSC compliance. Until then, the data on the cost performance report are suspect.

As shown in Table 2 in null form, there were three hypotheses. Hypotheses H1 and H2 compare the average current overrun to the average overrun at completion by the contractor and government during various stages of contract completion. In hypothesis H3, the average overruns at completion by the contractor and government are compared.

| TABLE 2. HYPOTHESES TESTED | | |
|---|---|---|
| **Null Hypothesis** | | **Interpretation** |
| $H1_0$: | CO ≤ KOAC | Contractor's OAC not optimistic |
| $H2_0$: | CO ≤ GOAC | Government's OAC not optimistic |
| $H3_0$: | GOAC ≤ KOAC | Government more optimistic than contractor |

*Note.* KOAC = Contractor's overrun at completion; GOAC = Government's overrun at completion.

If hypothesis H1 is rejected, the KOAC is unrealistically optimistic. If hypothesis H2 is rejected, the GOAC is unrealistically optimistic. If hypothesis H3 is rejected, the contractor is more optimistic than the government regarding the projected overrun at completion. A one-tailed "*t* test" was used to evaluate each hypothesis at the 95 percent level of confidence.

# Results

As illustrated in Figure 2, the hypotheses were generally confirmed. From as early as the 10 percent completion point, the optimism of the projected cost overrun at completion is apparent. Throughout the life of the contract, this estimate was found to be lower than the present and final cost

overruns. Also note that the average overrun at completion projected by the contractor was more optimistic than the average overrun at completion projected by the government program office.

Figure 3 shows that the difference between the overruns is statistically significant through most stages of contract completion. When the one-tailed "$t$ statistic" exceeds a critical value of 1.67 ($t_a$ = .05 statistic > 1.67), the difference is defined as significant at the 95 percent level of confidence.

As illustrated in Figures 4 through 6, these results were generally insensitive regarding the contract type, contract phase, type of weapon system, and the military service that managed the contract. To facilitate comparisons, the scales of the graphs are the same. The statistical significance of the differences between the overruns was generally confirmed for each category examined. The details, however, are not reported here.

# Conclusion

Based on an analysis of 64 completed contracts, the overruns at completion predicted by the contractor and by the government program office were unrealistically optimistic. From as early as the 10 percent completion point through the end of the contracts, the predicted final overruns were less than the current overruns reported on the contracts.



**FIGURE 2. OVERRUN OPTIMISM (64 CONTRACTS)**

**FIGURE 3. HYPOTHESES CONFIRMED (FOR $t_\alpha$ = .05 statistic > 1.67)**

**Statistical Significance (64 Contracts)**

Hypotheses

- H1: CO > KOAC
- H2: CO > GOAC
- H3: GOAC > KOAC
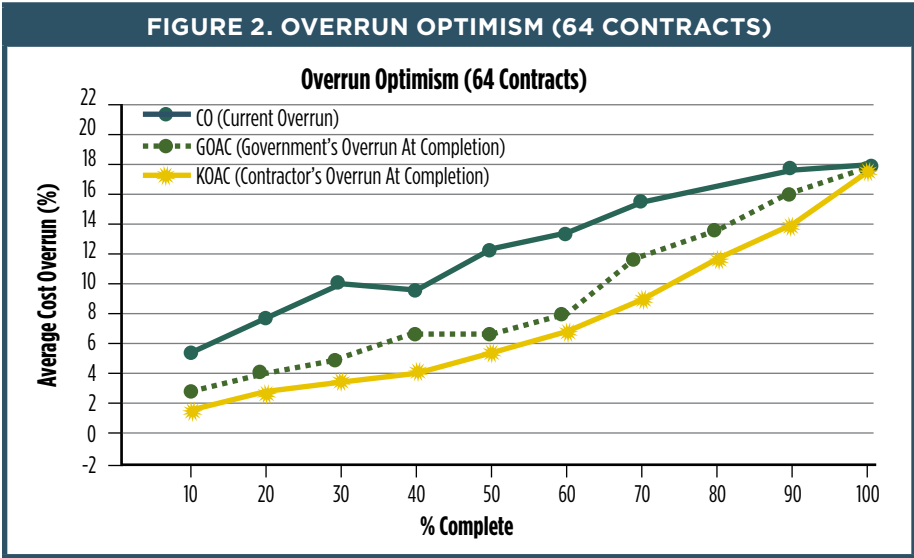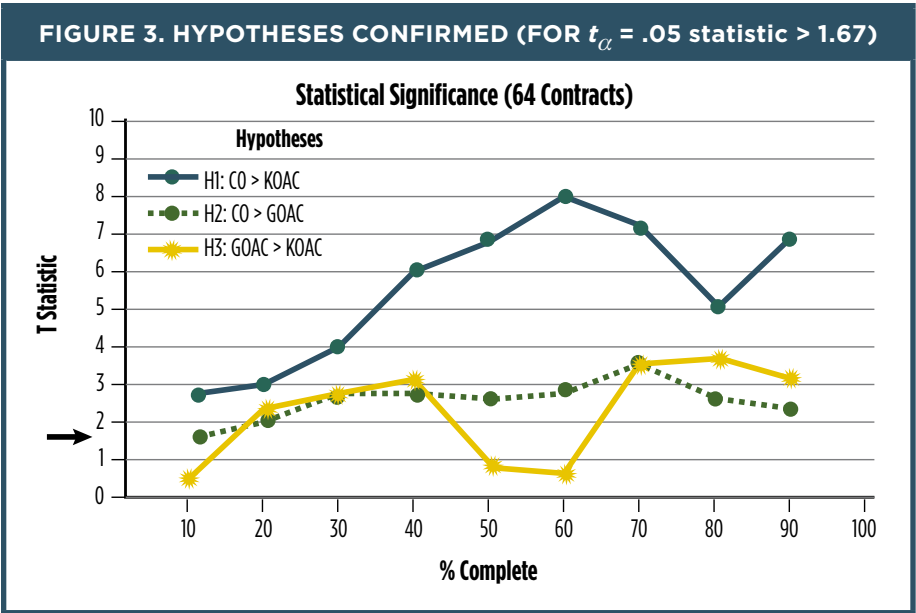
Although the estimates supported by the government program offices were less optimistic than the contractors' estimates, neither was found to be realistic.

Donald J. Yockey (1991), then Under Secretary of Defense (Acquisition), called for more realism throughout the acquisition process, including estimating realism.

> We can't afford to understate, sit on, or cover up problems in any program-at any time-at any level. They must be brought forward. This includes not just 'show stoppers' but also 'show slowers.' I can't stress this strongly enough (p. 36).

## FIGURE 4. AVERAGE COST OVERRUNS BY CONTRACT TYPE

### Overrun Optimism (41 Price Contracts)



- CO (Current Overrun)
- GOAC (Government's Overrun At Completion)
- KOAC (Contractor's Overrun At Completion)

Average Cost Overrun (%) — % Complete

### Overrun Optimism (23 Cost Contracts)



- CO (Current Overrun)
- GOAC (Government's Overrun At Completion)
- KOAC (Contractor's Overrun At Completion)

Average Cost Overrun (%) — % Complete
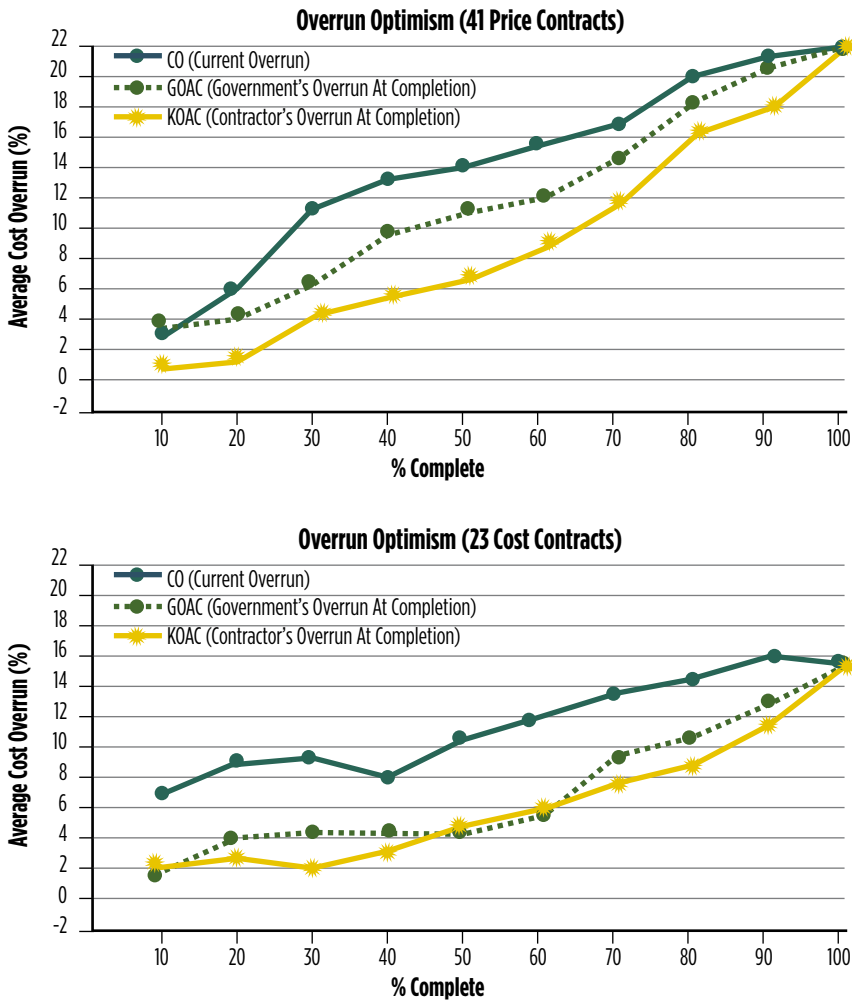
In an interview between the author and Wayne Abba, a respected analyst at the Office of the Under Secretary of Defense (Acquisition), Abba commented that adverse trends can be reversed if management pays attention to them (W. Abba, personal communication, 1992). Until contractors and program offices are willing to support and advance realistic assessments of a program's status, the attention and expertise of upper-level management is postponed, undoubtedly, in the long run, to the detriment of the program and nation. The famous economist Keynes once stated that, in the long run,

we are all dead (Homgren & Foster, 1991). Postponing or hiding adverse information about a program may be an effective short-run strategy; but, in the long run, it could result in the cancellation of the program.

## FIGURE 5. AVERAGE COST OVERRUNS BY CONTRACT PHASE

**Overrun Optimism (25 Development Contracts)**



**Overrun Optimism (39 Production Contracts)**
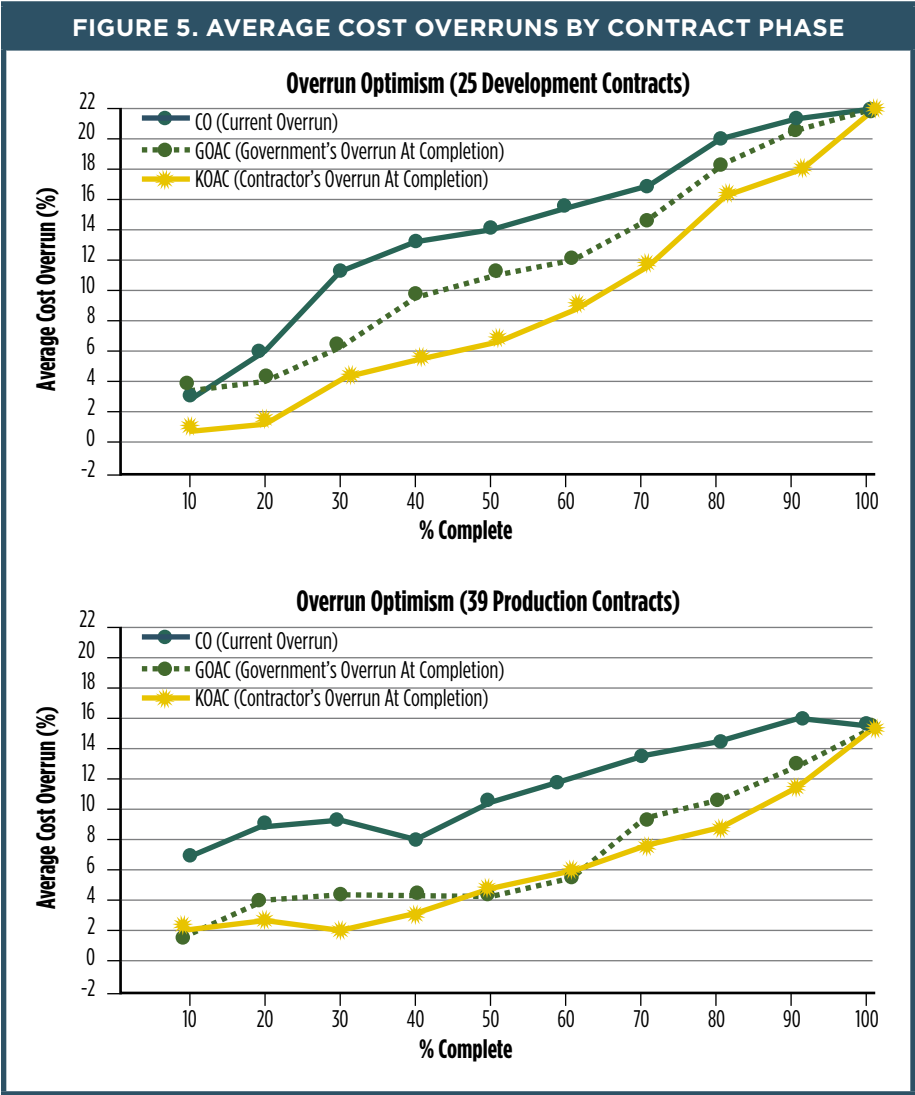
## FIGURE 6. AVERAGE COST OVERRUNS BY TYPE OF WEAPON SYSTEM

### Overrun Optimism (43 "Air" Contracts)



- CO (Current Overrun)
- GOAC (Government's Overrun At Completion)
- KOAC (Contractor's Overrun At Completion)

### Overrun Optimism (13 "Ground" Contracts)



- CO (Current Overrun)
- GOAC (Government's Overrun At Completion)
- KOAC (Contractor's Overrun At Completion)

### Overrun Optimism (8 "Sea" Contracts)



- CO (Current Overrun)
- GOAC (Government's Overrun At Completion)
- KOAC (Contractor's Overrun At Completion)

**FIGURE 7. AVERAGE COST OVERRUNS BY MANAGING SERVICE**
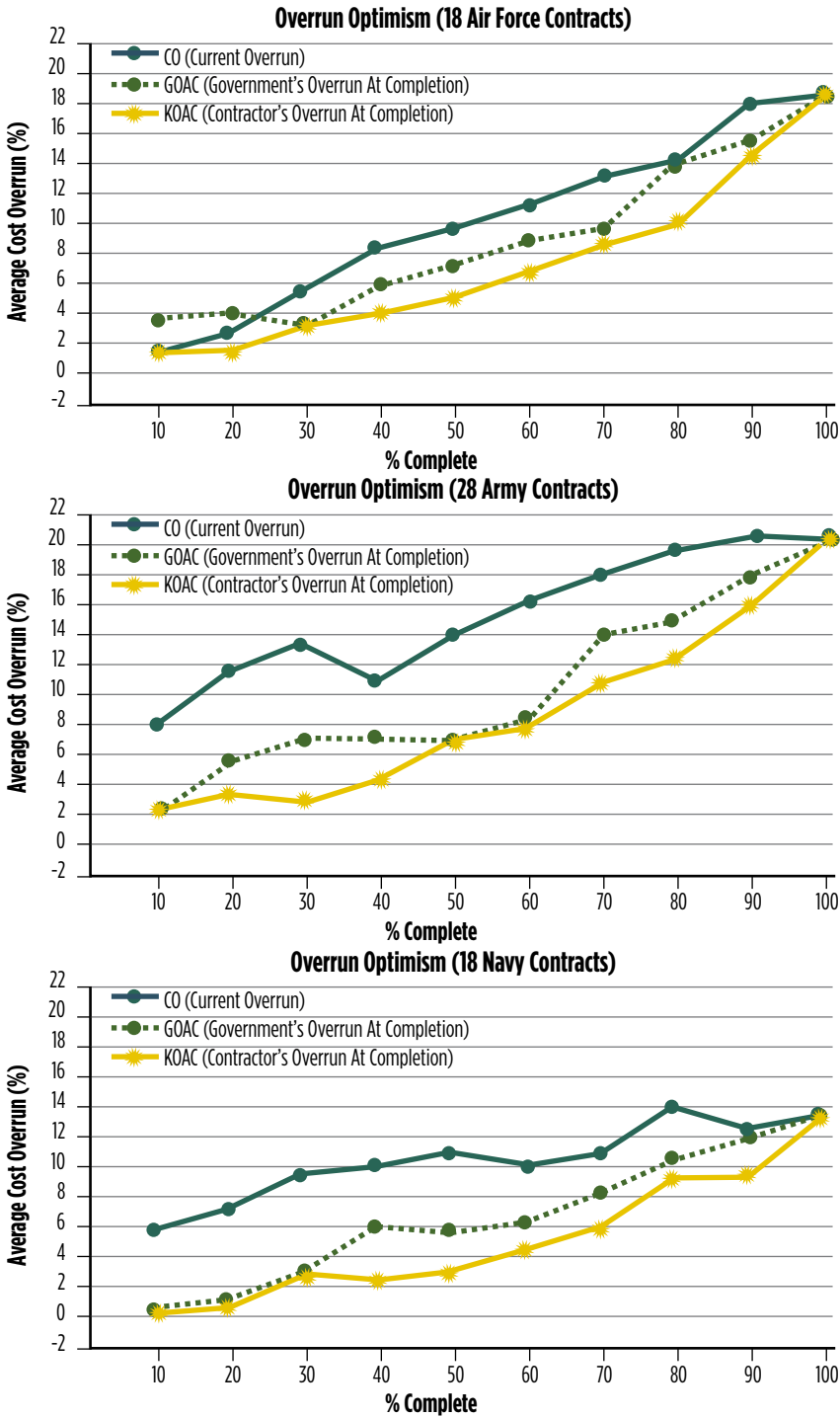
# References

Beach, C. P. (1990). *A-12 administrative inquiry: Report to the Secretary of the Navy.* Washington, DC: Department of the Navy.

Campbell, D. G., & Fleming, Q. W. (1991, January 17). *The A-12 program management summary.* Paper presented by W. Abba at National Security Industrial Association/Multispectral Scanner System (NSIA/MSS) meeting, Los Angeles, CA.

Christensen, D. S. (1989, Fall). Management control systems theory and cost/schedule control systems criteria. *National Estimator,* 29–34.

Christensen, D. S., & Payne, K. (1992, April). Cost performance index stability—Fact or fiction? *Journal of Parametrics, 10,* 27–40.

Christle, G. L. (1981, Spring). Automation of program-project cost reports within DOD. *National Estimator, 1,* 22–27.

Department of the Air Force. (1987). *Cost/schedule control systems criteria joint implementation guide* (Air Force Systems Command Pamphlet 173-5). Washington, DC: Headquarters Air Force Systems Command.

Department of the Air Force. (1989). *Guide to analysis of contractor cost data* (Air Force Systems Command Pamphlet 173-4). Washington, DC: Headquarters Air Force Systems Command.

Department of Defense. (1991). *Defense acquisition management policies and procedures* (Department of Defense Instruction 5000.2). Washington, DC: Author.

Ferber, M. M., & Math, P. F. (1991, April 9). *A-12 default termination issues.* United States General Accounting Office Testimony–Joint statement before the House Armed Services Committee and Subcommittee on Investigations (GAO/T-NSIAD-91-14). Washington, DC: General Accounting Office.

Gansler, J. S. (1989). *Affording defense.* Cambridge, MA: The MIT Press.

Heise, S. R. (1991). *A review of cost performance index stability* (Report No. AFIT/GSM/LSY/91S-12). Master's thesis, School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson Air Force Base, OH.

Homgren, C. T. (1990). In G. Foster (Ed.), *Cost accounting: A managerial emphasis* (7th ed.). Englewood Cliffs, NJ: Prentice Hall.

Morrison, D. C. (1991, March). Deep-sixing the A-12. *Government Executive, 23,* 30–35.

Welch, J. J. (1991). *Program Advocacy* (Acquisition Policy Letter 91M–005).

Wilson, B. D. (1991). *An analysis of contract cost overruns and their impacts* (Report No. AFIT/GCAILSY/92S-8). Master's thesis, Air Force Institute of Technology, Wright-Patterson Air Force Base, OH.

Yockey, D. J. (1991, Winter). Keynote presentation at the Cost/Schedule Control Systems Criteria National Workshop, Falls Church, VA. *National Estimator,* 35–38.

# **Endnotes**

[1] Responses from an interview with J. J. Welch, which appeared in the Acquisition Policy Letter 91M-005 dated April 8, 1991.

[2] Compliance to C/SCSC is required on significant contracts and subcontracts within all acquisition programs. Significant contracts are research, development, test and evaluation contracts with an estimated cost of $60 million or more (in fiscal 1990 constant dollars) or procurement contracts with an estimated cost of $250 million or more (fiscal year 1990 constant dollars) (Department of Defense, 1991, p. 11–B-2).

## Author Biography

At the time "Cost Overrun Optimism: Fact or Fiction?" was published, **Dr. David D. Christensen** was an Air Force major and an associate professor of accounting at the Air Force Institute of Technology Graduate School of Logistics and Acquisition Management at Wright-Patterson Air Force Base, Ohio. He holds a PhD in Accounting.

*(E-mail address: christensend@suu.edu)*

*Image designed by Diane Fleischer*
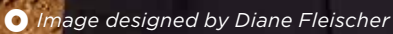
# Systemic Fiscal **OPTIMISM** in **Defense Planning**

*Leland G. Jordan*

Defense planning and budgeting increase national security costs by significantly overestimating available future resources. An analysis of Department of Defense out-year resource estimates over a period of 20 years and six administrations—the first econometric analysis of budgeted and realized resources in defense—demonstrates that an optimistic bias has spanned administrations and appears to be a systemic characteristic rather than a political one. The result has significant implications for reduction of defense costs without loss of capability.

# Systemic Fiscal Optimism in Defense Planning

Some analysts have suggested that fiscal optimism in defense planning and budgeting results in less defense than could have been achieved given the resources available. That is, fiscal optimism results in less bang for the buck, rather than the more bang for the buck traditionally sought by the Department of Defense (DoD). Programs established under a projected fiscal regime with more resources than later are realized may become unaffordable under the tighter resource constraint. Unaffordable means that the budget is not sufficient to carry out the program at the rate, at the unit cost, and in the quantities originally programmed and planned.

The traditional issue of weapons systems cost growth and the issue of DoD's consistent forecast that it will receive significantly more budgetary resources than it actually receives are not separate. The gap between planned and realized budgetary resources is the predominant cause of weapons systems cost growth.

Franklin Spinney addressed the problem of cost growth and fiscal optimism in the early 1980s. His analysis was not well received within DoD, although it achieved sufficient notoriety outside DoD: He was pictured on the cover of *Time* magazine (Isaacson, 1983). He addressed the force structure and unit cost problems that result from optimistic assumptions about the cost progress curves[1] and the reluctance to terminate systems that, although well along in development or production, appear unaffordable given the resources actually appropriated (Spinney, 1980). Spinney did not address how DoD consistently gets into the position of not having enough resources to complete what it has started.

Gansler approaches the issue through the effects on weapons system costs and on strategy and the ability to support strategy (Gansler, 1989, chap. 5). Focusing primarily on management within DoD and on the interface with industry, Gansler addresses "optimistic planning," but does not directly address the source of fiscal overoptimism. The Packard Commission identified the problem of optimistic planning and recommended some improvements, but did not present an analysis demonstrating the persistence of the phenomenon across time and administrations (Packard, 1986). Efforts to assess the dollar effect of optimistic planning have been rare and have not been published in the academic press. For example, Rolf

Clark's papers, prepared under the auspices of the DoD's Defense Systems Management College and circulated within the DoD, were not published in peer-reviewed journals (Clark, 1990a, 1990b).

This article provides an assessment of the quality of the defense out-year resource forecasts from a system perspective, identifies the source of forecast errors, and draws implications about their costs and the potential for improving the forecasts. Its broader purpose is to identify the nation's out-year budgeting practices as an important area of research in which analysts can contribute significantly to the national welfare. Budgeting, whether for next year or longer periods, is an accountancy function directly affecting management; it should be addressed with the same rigor as is applied to stock price movements, earnings forecasts, and the effects of revised standards.

This analysis is based on the following axioms. If one plans to have significantly more resources than become available then it should not be surprising if the plans are unaffordable. The planner should learn from such experience and begin to estimate better the future resources. We should not expect a perfect forecast, but should expect the quality of the forecasts to improve over time.

Forecast accuracy is especially important for national defense when erroneous forecasts contribute to a lesser capability than could have been obtained at the realized resource level.

The analysis presented here concludes that the defense planning and budgeting system is optimistically biased and that the bias has spanned several administrations. Nonetheless, out-year forecasts have been significantly better under some administrations than under others. Those administrations having demonstrated the greatest bias in their real growth projections also have experienced the greatest shortfalls in resources, implying the greatest impact on management. A proportion of the forecast error can be reduced and improvements (discussed below) can be instituted.

Neither this analysis nor those cited suggest that optimistic planning results from malicious intent. Rather, it is the result of a highly complex system that does not function as intended.

Optimism is defined as a form of the bias discussed in the conceptual statements of the Financial Accounting Standards Board (FASB). Were we able to place a probability distribution on the fiscal projections of the defense budget, we would find that those projections consistently are greater than the expected value. No attempt is made to assign the causes of the bias to the elements of measurer bias or measurement bias. Measurer bias results when the measurer misapplies the measurement methodology. Such misapplication may derive from lack of skill or lack of integrity, or both. Measurement bias results from inadequacy, or lack of validity, of the measurement instrument or method. However much the resultant bias may originate in each of those two causes, it remains a systemic characteristic of the national security planning and budgeting system (FASB, 1985).

# The Impact on Military Effectiveness

Planning for more resources than become available results in programming a larger force and more investments than can be supported. The defense literature has noted the effects of that discrepancy. Kevin Lewis, in "The Discipline Gap and Other Reasons for Humility and Realism in Defense Planning," concludes that the likelihood of the DoD's planned program achieving its planned effectiveness is small (Lewis, 1994). It is important to recognize that Lewis has in mind the military effectiveness of the forces that result from the plans. Jacques S. Gansler deals with the effects on weapons system costs and on strategy and the ability to support strategy (Gansler, 1989). Spinney also has addressed these effects (Spinney, 1996).

In defense planning, the mix and deployment of forces is optimized within the expected resource constraints.[2] The mix of forces varies as a function of the total financial resources available. For example, a specialized aircraft or other weapons system may be effective and affordable only if it exists in the force in some minimum quantity. Fielding of the system requires development of doctrine and tactics and also the training of the forces and the commanders. In the highly integrated modern battlefield, development and management of compatibility with the associated forces also is required. Clearly, it could be ineffective and cost-prohibitive to do all those things for a single aircraft, especially if some backup weapons system was required in the event that single aircraft were lost. At some point, the cost effectiveness of a specialized system, available in a minimum quantity, is less than the cost effectiveness of the alternative multipurpose weapons system.

Decisions to produce a special-purpose weapons system or the alternative multipurpose system are made on the basis of projected resources. Even once it becomes clear that resource projections were optimistic, reversing such decisions is difficult. The difficulties arise from the added costs incurred by a termination, both economic and psychological, and from the time-lag that would be incurred in developing the multipurpose system. In fact, that time-lag may preclude fielding of the alternative capability soon enough to counter the threat. Thus, the ability to repair a bad decision in response to near-term information about resource availability is limited.

Given the earlier decisions, made on the basis of optimistic resource projections, the best possible defense program may be significantly less effective than would have been possible had the earlier decisions been made in the context of realistic resource constraints. That situation is modeled below:

Let $E$ (year, resources, period) represent the maximum effectiveness of the defense program resulting from decisions made in year $i$, given multiyear projected resource constraint $j$, and serving in the future period $k$. The period may be a specified Future Years Defense Program (FYDP)[3] period or some longer time span (such as a decade). Then, the maximum effectiveness of a defense program, given resource constraint $j_1$, is

$$E(i, j_1, k) \tag{1}$$

and the maximum effectiveness of the next year's defense program, covering the effectiveness of the next year's defense program, covering the same period $k$, but with a revised resource constraint $j_2 < j_1$, is

$$E(i + 1, j_2, k) < E(i, j_1, k). \tag{2}$$

Some observers have identified the revised planning that results from correction of $E(i, j_1, k)$ to achieve $E(i + 1, j_2, k)$ as the source of the acquisition turbulence so roundly condemned by the Packard Commission (1986). Clearly, if the effectiveness decline applies to the next year's program, it also applies to the $i + n$ program where $n$ is an integer greater than one and less than some integer representing the time to develop and field an improved mix of forces.

Because the time to develop and field a weapons system is at least 10 years, the effectiveness decline persists for about that same period.

# Other Analyses of Planning Bias

The idea that a bias in planning may exist is not new. Henri Thiel (1971) discusses the measurement of such bias and offers several examples of systemic bias. His discussion, because it uses Dutch national forecasts as an illustrative case, establishes the relevance of that technique to the analysis presented here. J. Chapman (1981) applied Thiel's technique to assessment of the accuracy of revenue forecasts by California cities before and after the passage of Proposition 13. He found a tendency toward underestimation of

revenues both before and after passage of Proposition 13. Chapman's findings are not directly relevant to this analysis, but his application of Thiel's technique is.

> **Alan Auerback, an economist at the University of California, Berkeley, commented, "I've become convinced that there's a pervasive tendency towards overoptimism in both agencies"**

Allusions to bias in national forecasts in the United States are not unusual. For example, D. Sessel (1995) quotes comments by two well-known observers on the White House and Congressional Budget Office (CBO) forecasts. Former CBO Director June O'Neill said, "The history over the past 20 years is that both of us are too optimistic." Alan Auerback, an economist at the University of California, Berkeley, commented, "I've become convinced that there's a pervasive tendency towards overoptimism in both agencies" (Sessel, 1995). In *Affording Defense*, Gansler (1989, chap. 5) refers to "optimistic planning." One of the threads of his analysis is the effect of planning for a greater financial resource than becomes available. Gansler is unusual in his recognition of the adverse effects of such optimism.

The existence of such a systemic bias is relevant to other organizations, both public and private, and knowledge about the detection and correction of such biases would be an important contribution to the knowledge about managing complex public and private organizations. The magnitude of the effect on other organizations probably is related positively to their planning horizon.

## Bias in Defense Planning

### Data

For this study we examined data for a period of 20 years: fiscal year 1975 through fiscal year 1995.[4] Planned resource levels were compared to the actually available resource levels for the administrations of Presidents Gerald Ford, Jimmy Carter, Ronald Reagan, George Bush, and for President Bill Clinton through fiscal year 1995.

The projected fiscal resources against which plans were constructed consistently exceeded the fiscal resources that actually became available. The situation is portrayed graphically in Figure 1. That figure presents the actual and planned data for President Reagan's second administration, 1985 through 1988.

The bars in the chart show the resource levels for each year of the DoD's planning period. Because a new planning period begins yearly, the bars for each year represent plans from several prior years. The line represents the funding appropriated by the Congress, the fiscal resources that was realized resource that was realized. Clearly, the plans of each administration extend into the subsequent administrations and, just as clearly, are revised by those subsequent administrations.



FIGURE 1. PLANNED VERSUS REALIZED REAL GROWTH, FISCAL YEARS 1985–88
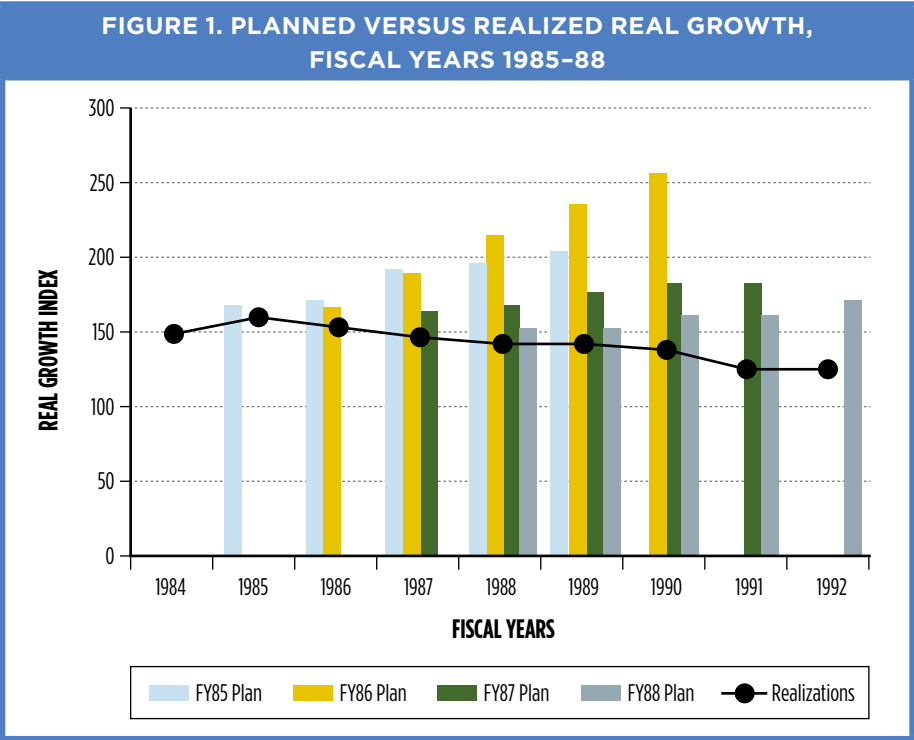
In order to remove the effects of inflation, real dollar levels indexed on fiscal year 1974 are plotted. The DoD deflators were applied to the actual appropriations. Those projected at the time of each plan were used to deflate the resource projections, and then were linked to the same deflators that were

applied to the series of actual appropriations. Thus, each year's resource levels, projected and actual, were restated in the same dollars and then indexed on fiscal year 1974.

## Methodology

Spinney (1992) used a primarily graphical analysis in his presentations, accompanied by discussion. Figure 1 similarly portrays the data. Graphical portrayals provide an intuitive feel for the situation, but they do not support conclusions about the underlying causes of the forecasting errors.

In *Applied Economic Forecasting*, Thiel (1971, p. 32) develops a method for analyzing the adequacy of economic forecasts. Thiel decomposes the squared error of the forecast into coefficients related to the sources of the forecasting error.

Our analysis is based on real growth rates, projected and actual, to remove the effects of inflation and also because the projection methodology used in the DoD is based largely on assumptions of future real growth. The analysis uses the natural logarithms of the real growth rates. Their use ensures that the levels in years $t_1$ and $t_2$ are the same if the log changes in those years are equal but of opposite sign (Thiel, pp. 47–50).

## Sources of the Projection Errors

Thiel's coefficients are derived from the sum of the squared errors as shown below in Figure 2. The coefficients represent bias, variance, and covariance, respectively.

### FIGURE 2. THE SUM OF THE SQUARED ERRORS

$$\frac{1}{n}\Sigma\ (P_i - A_i)^2 = (\overline{P} - \overline{A})^2 + (S_p - S_a)^2 + 2(1-r)S_p S_a \qquad (3)$$

$$1 = \frac{(\overline{P} - \overline{A})^2}{\frac{1}{n}\Sigma\ (P_i - A_i)^2} + \frac{(S_p - S_a)^2}{\frac{1}{n}\Sigma\ (P_i - A_i)^2} + \frac{2(1-r)S_p S_a}{\frac{1}{n}\Sigma\ (P_i - A_i)^2} \qquad (4)$$

# Analysis of the Data

Table 1 presents data about the frequency of the forecasting errors. Table 2 presents the coefficients and is followed by a discussion of their meaning.

As Table 1 shows, the real growth rate used in DoD's resource projections exceeded the real growth rate realized in the amounts appropriated in 66 of 94 fiscal years (70 percent of the projections). The effects of inflation have been removed from both the resource projections and the appropriated amounts. The optimistic tendency (70 percent of the projections exceeded the actual appropriations, in real dollars, vice the approximately 50 percent in an unbiased system), therefore, is not a result of the difficulty of forecasting inflation rates.

## Bias

The bias proportion represents deviations in central tendency. It shows the proportion of the root mean square error that results from the difference between the mean of the predictions and the mean of the realizations. Positive values for the difference in the means of the predicted and realized values indicate that, on the average, higher real growth rates are projected than are realized.

In five of the six administrations the mean prediction exceeded the mean realization. The importance of that bias is indicated by the bias proportions in Table 2. In each of President Reagan's administrations, about 75 percent of the error in projections derived from optimism about how much Congress would appropriate. In President Bush's administration, about 49 percent of the projection error resulted from an upward bias. About 27 percent of the projection error in President Clinton's first two years resulted from overly optimistic projections. President Ford's administration exhibited very little bias. About 0.3 percent of his projection error resulted from general overoptimism.

| TABLE 1. FREQUENCY OF FORECASTING ERRORS | |
|---|---|
| Number of periods forecast | 94 |
| Forecast real growth rate exceeded actual rate | 66 |
| Actual rate exceeded forecast | 28 |

| TABLE 2. INEQUALITY PROPORTIONS | | | |
|---|---|---|---|
| **Administration** | **Bias** | **Variance** | **Covariance** |
| Ford | .00322 | .23899 | .75779 |
| Carter | .33380 | .32189 | .34431 |
| Reagan I | .75237 | .03787 | .20976 |
| Reagan II | .75249 | .00044 | .24707 |
| Bush | .48722 | .05170 | .46109 |
| Clinton | .26872 | 43326 | .29802 |

In contrast, President Carter's administration exhibited a bias below what the Congress appropriated, accounting for about one-third of the projection error.

## Variance

The variance proportion is zero only if the standard deviations of the projected and realized real growth rates are the same. As Table 3 indicates, for the administrations of Presidents Ford, Carter, and Bush and for President Reagan's first administration, the variance of the realizations exceeded the variance of the projections. For each of those administrations, the projected real growth rate fluctuated less from year to year than did the achieved real growth resulting from congressional appropriations. For Presidents Reagan and Bush, this difference in consistency contributed

only about 3.8 percent and 5.2 percent, respectively, of their projection error, making that source relatively unimportant compared to the effect of the upward bias in central tendency. During the Carter and Ford administrations, the difference in consistency was relatively more important, contributing 32 percent and 24 percent, respectively, of the projection error.

Conversely, in President Reagan's second administration and in the first two years of President Clinton's administration the projections have been less tightly distributed than have the congressional appropriations.

| TABLE 3. MEANS, STANDARD DEVIATIONS, AND CORRELATIONS | | | |
|---|---|---|---|
| Administration | $P - A$ | $S_p - S_a$ | $r$ |
| Ford | .0028 | -.0238 | -.0736 |
| Carter | -.0294 | -.0289 | .0820 |
| Reagan I | .0522 | -.0117 | .7325 |
| Reagan II | .4934 | .0019 | .0937 |
| Bush | .0436 | -.0141 | .1458 |
| Clinton | .0123 | .0156 | .8524 |

One might hypothesize that the pattern of the variance relationship indicates that Presidents Ford, Carter, Bush, and Reagan (in his first term) had a better-defined vision, or at least a firmer vision, for the national security than did the Congress. Such a hypothesis would accept year-to-year consistency in appropriations as a proxy for a consistent vision. A full examination of that hypothesis, however, is beyond the scope of this paper; for the present, we leave it for others to address. As one reviewer noted, however, it might be addressed through an analysis of the concurrent resolutions on the budget.[5]

## Covariance

The covariance proportion is zero only if the coefficient of correlation is 1. As indicated in Table 3, the directional agreement, the correlation, between the administration's real growth projections and the congressional appropriations, has been highest in President Reagan's first term and in President Clinton's first two years. President Ford and the Congress moved in opposite directions. The correlations in President Carter's administration, President Reagan's second administration, and President Bush's administration are all positive, but quite low. The difference in correlation contributed relatively significantly to the projection error in the Ford administration, less so in the Bush administration, and progressively less so in the Carter, Clinton, and Reagan administrations.

The preceding analysis addressed the sources of the projection error on a relative basis. If the projection error is small, then the importance of a relatively large proportional contribution also is small. Thus, it is important to address the size of the projection errors. Did the administrations have similar projection errors, or did some administrations experience notably large projection errors? What was the source of any larger-than-typical errors?

## Sizes of the Projection Errors

Table 4 presents the average sizes of the projection errors as a percentage of the planned resource level; that is, as a percentage of the projection. Importantly, for Table 4, the calculation is based on the planned resource level (in constant dollars), not on the year-to-year real growth rates, and is not represented logarithmically. The resource-level base portrays the effect on program management better than do the calculations based on year-to-year rates.

| TABLE 4. SIZE OF RESOURCE SHORTFALLS | |
|---|---|
| **Administration** | **Mean Shortfall as Percent of Planned Resource Level** |
| Ford | -5.3 |
| Carter | +10.9 |
| Reagan I | -13.4 |
| Reagan II | -19.5 |
| Bush | -11.1 |
| Clinton | -2.5 |

*Note.* A minus sign indicates available resources were less than planned. The comparison is across the periods projected during each Presidential term.

It is the error in projecting year-to-year real growth rates that causes the resource shortfalls and that error is an accurate portrayal of the overoptimism. The overly optimistic projection of future resources derives from the overly optimistic projections of real growth. Nonetheless, once resources are realized, it is the resource quantity that constrains management of operations and investment. Hence, the importance of those shortfalls is better measured as a function of the resource levels. Note that measurement using the resource levels makes each year's error dependent on the cumulative effect of the prior years' errors, as it in fact is.

Of the six administrations, only President Carter's projected less in resources than were realized. It is enlightening, however, to look at the timing and circumstance of those in-excess-of-projected realizations. During President Carter's tenure, the Congress appropriated an average of 4.9 percent more than President Carter requested. The Carter administration projections for his post-tenure years, fiscal years 1982 through 1986, were significantly less than Congress appropriated for those years. President Carter's plans for those post-tenure years were overfunded by an average of 13.8 percent of those plans.

Thus, President Carter's average resource overrun of 10.9 percent compared to his out-year projections can be attributed largely to President Reagan's military buildup. The Carter administration's bias to the low side of those realizations appears to be a result of a changed national security policy and perception.

Conversely, the existence of overfunded plans during President Carter's tenure confirms that it is possible for a President to overcome the systemic fiscal overoptimism of the defense establishment. Of the six administrations analyzed, only the Carter administration presented requests to the Congress that were less than the amount ultimately appropriated by the Congress. If we conclude that the defense budget process includes a systemic overoptimism, then we are led to conclude that President Carter managed to overcome that systemic bias.

Spinney (1996) offers a description of the pressures to increase budget allocations that the defense establishment can place on a President. His recounting of the pressures and maneuvering leading to the 1996 increases in the future-years program provides considerable insight into the difficulties a President faces in overcoming defense's tendency to optimistic out-year fiscal projections.

### Correlation of Projection-Error Size and the Bias Coefficient

Those administrations having the largest projection errors, as measured by Table 4, also exhibit the largest bias coefficients. Consider Table 5. The apparently high correlation is confirmed by a Spearman Rank correlation test. That test, yielding a rank correlation coefficient of 0.94, is significant on a one-sided test with a type I error of 0.02.

| TABLE 5. CORRELATION OF ERROR SIZE AND BIAS | | |
|---|---|---|
| **Administration** | **Absolute Value of Mean Shortfall as Percent of Planned Resource Level (%)** | **Bias Coefficient (%)** |
| Reagan II | 19.5 | 75.25 |
| Reagan I | 13.4 | 75.24 |
| Bush | 11.1 | 48.72 |
| Carter | 10.9 | 33.38 |
| Ford | 5.3 | 3.22 |
| Clinton | 2.5 | 26.87 |

Thus, over the past 20 years, those administrations that exhibited significant bias (optimistic or pessimistic) in their resource projections, tended also to have relatively large errors in their projections of resources.

Consider Table 6, which is Table 2 reordered from the largest to the smallest projection error, except for the Ford administration. If we accept that President Ford's projection error derived primarily from his directional differences with the Congress, then the evidence becomes more persuasive.

| TABLE 6. INEQUALITY PROPORTIONS ORDERED BY SIZE OF PROJECTION ERROR (EXCEPT FOR FORD ADMINISTRATION) | | | |
|---|---|---|---|
| **Administration** | **Bias** | **Variance** | **Covariance** |
| Reagan II | .75249 | .00044 | .24707 |
| Reagan I | .75237 | .03787 | .20976 |
| Bush | .48722 | .05170 | .46109 |
| Carter | .33380 | .32189 | .34431 |
| Clinton | .26872 | . 43326 | .29802 |
| *Ford* | *.00322* | *.23899* | *.75779* |

If the bias coefficient is large, then the average predicted change is substantially different from the average realized change. If bias remains a major source of error over time, then the forecasting system is not improving. That is a serious error. The covariance error source should not be expected to approach zero. Were that true, the line of predictions and realizations would be straight. Such an exact alignment is too much to expect (Thiel, 1971, p. 32).

## Efforts to Correct the Bias Error

Bias has been recognized as a serious source of error by an independent commission and within the Department of Defense (Gansler, 1989; Packard, 1986; Spinney, 1996). Recognition within the Department is difficult to document because internal DoD management and financial management policy analyses are not publicly available. Nonetheless, there has been sufficient occasional recognition of fiscal overoptimism as a management problem to support the conclusion that the professional career staff was aware of it and of its deleterious effects (Clark, 1990a; Clark, 1990b; Jordan, 1990; Lewis, 1994).

The Packard Commission (1986) focused intensively on the tendency to overestimate the future resources as a serious management problem. That Commission's report, together with pressure from career executives, fostered a limited recognition of the need to improve the forecasting of resources.

# Conclusions and Recommendations

A tendency exists for the Defense Department to project the availability of significantly more resources than become available. Historically, those administrations having demonstrated the greatest bias in their real growth projections also have experienced the greatest shortfalls in resources. Hence, those administrations having demonstrated the greatest bias in their real growth projections also most seriously handicapped program managers. Projecting significantly more resources than become available directly affects force mix and capability. The force-mix optimization studies used in programming decisions incorporate a resource constraint.

The existence of optimistic bias has spanned administrations. It continues despite changes of administrations—whether the political party of the incoming administration is the same or changes. It appears, therefore, that the bias results from some characteristic of the defense management system; it is a systemic phenomenon. So it appears reasonable to conclude that reducing the optimistic bias will require changes to the planning and budgeting system. In undertaking such changes, it is important to recognize that bias reduction is the goal, not elimination of the projection error.

There clearly is room for improvement in the Defense planning and budgeting system. The analysis in this article is empirical. It establishes existence of a systemic bias in one the nation's major accounting and budgeting systems. Gansler (1989) and Clark (1990a, 1990b) each have identified

significant costs arising from budget turbulence in DoD. The systemic bias identified here is a source of that turbulence. It seems reasonable to suggest that other analysts could contribute significantly to the national welfare via rigorous development of improved forecasting methods that would be unbiased. A broad proposal for such research is outlined below.

Changes in the planning and budgeting system to reduce optimistic bias should be based on a review that identifies the decision points and techniques of the system. Techniques include the modeling and projection methodology; for example, regression analysis, auto regressive integrated moving average (ARIMA), or dynamic economic models. Decision points are those places in the process where out-year assumptions are made. Examples of these are whether DoD will receive a greater or smaller share of the U.S. budget, whether the U.S. budget will increase or decrease, and the size of the applicable growth rates.

Because the analysis identifies a period in which the systemic bias was corrected, a comparison of that period to other periods appears potentially fruitful. The first step in such research might be structured interviews with senior officials and analysts who played key roles in the planning and budgeting process under the Carter administration and other administrations.

Three sources of projection error were identified: bias, variance, and covariance. It is reasonable to expect that forecasting systems should exhibit the ability over time to diminish the bias source. Not to do so indicates lack of continuing improvement in the forecasting system. The time trend of bias errors does not indicate any systemic improvement. From a system perspective, the national defense planning system is not functioning as it should. The variance error source appears to result from the relative consistency of the administration's vision of the national defense versus the consistency of the Congress's vision. Testing and analysis of that hypothesis is deferred, but changes to the forecasting system appear an unlikely way to improve the correlation of the Administration's and the Congress's vision for national defense.

The covariance error source should be expected to continue; further, improvements in the forecasting system that reduce the bias source almost surely will increase the relative size of the covariance error source.

# References

Chapman, J. (1981, Summer). Fiscal stress and budgetary activity. *Public Budgeting and Finance, 2*(2), 83–88.

Clark, R. (1990b). *Defense budget: A costly malpractice* (research paper). Fort Belvoir, VA: Defense Systems Management College.

Clark, R. (1990a). *The dynamics of budget instability* (research paper). Fort Belvoir, VA: Defense Systems Management College.

Financial Accounting Standards Board (FASB). (1985). *Qualitative characteristics of accounting information: Statement of financial accounting concepts* No. 2. Stamford, CT: Author.

Gansler, J. S. (1989). *Affording defense*. Cambridge, MA: MIT Press.

Isaacson, W. (1983, March 7). The winds of reform. *Time*, 12–30.

Jordan, L. G. (1990). *Systemic fiscal overoptimism in defense management*. Presentation to the Washington Accounting Research Society, Loyola College, MD.

Joyce, P. (1996, July–August). Congressional budget reform: The unanticipated implications for federal policy making. *Public Administration Review, 56,* 317–325.

Lewis, K. N. (1994). The discipline gap and other reasons for humility and realism in defense planning. In P. K. Davis (Ed.). *New challenges for defense planning*. Santa Monica, CA: RAND.

Packard, D. (1986, June). *Report to the President by the President's Blue Ribbon Commission on Defense Management: National security planning and budgeting*. Washington, DC: The Packard Commission.

Quade, E. S., & Boucher, W. I. (1968). *Systems analysis and policy planning: Applications in defense*. Santa Monica, CA: RAND.

Sessel, D. (1995, November 3). The art of tweaking: White House's altered forecast on economy underlies Capitol Hill budget duel. *Wall Street Journal*,  p. A16.

Shick, A. (1996, Winter). The majority rules. *Brookings Review, 14,* 42–45.

Spinney, F. C. (1980, May). *Defense facts of life* [Staff paper]. Washington, DC: Office of the Secretary of Defense, Director, Program Analysis and Evaluation.

Spinney, F. C. (1992, May-June). Uncle Sam's budget shambles. *Challenge: The Magazine of Economic Affairs, 35*(3), 9–12.

Spinney, F. C. (1996, July–August). Defense time bomb: F–22/JSF case study hypothetical escape option. *Challenge: The Magazine of Economic Affairs,* 23–33.

Thiel, H. (1971). *Applied economic forecasting*. Amsterdam, The Netherlands: North Holland.

# Endnotes

[1] The optimistic assumption is production quantity, not slope.

[2] Optimization within resource constraints is well established in national security planning. The techniques and theory were set out 30 years ago by Quade and Boucher (1968). The Packard Commission's report (Packard, 1986) clearly reflects the continuation of that practice.

[3] A Future Years Defense Program covers a specified 6-year period for which DoD plans. A new FYDP period starts each biennium, thus constituting a rolling coverage of the future.

[4] Data are from DoD press releases, Secretary of Defense Annual reports to the Congress, and the National Defense Budget Estimates series published by the DoD Comptroller. Data for earlier years were not available. Although the "Historical FYDP" reaches back to fiscal year 1962, it does not present the original estimates. FYDP data are revised if appropriations change during the year and also to reflect actual obligations through time. In addition, documents presenting the original inflation forecasts are not available and such original projections are necessary to restate the out-year data in constant dollars.

[5] Analyses of the congressional budget process are in Joyce (1996) and Shick (1996).

## Author Biography

At the time "Systemic Fiscal Optimism in Defense Planning" was originally published, **Dr. Leland G. Jordan** was an associate professor in the School of Business at Christopher Newport University, Newport News, Virginia. A retired member of the Senior Executive Service, Dr. Jordan has a DBA from George Washington University, an MS (Systems Analysis) from the Air Force Institute of Technology, and a BS from the University of Florida. He has published in a number of academic and professional journals.

*(E-mail address: ljordan@cnu.edu)*

# Resilience—A
# CONCEPT

*Col Dennis J. Rensel, USAF (Ret.)*

Resilience takes on many definitions and ideas depending upon who is speaking. Taking this one step further, consider resiliency as a concept that provides a holistic view of a system or capability, just as biomedical indices provide an indication, a concept of a person's health. This process or concept of assessing one's health can be equated to the assessment of the health of a network or system. The hypothesis is: resiliency is meaningful in the context of holistic assessments of capabilities. At this level, comparisons of capabilities or systems can lead to informed decisions about resources, funding, and tradespaces. This article develops a Resiliency Tier Matrix and illustrates how to obtain a holistic view of resilience for a capability or system.

*Image designed by Diane Fleischer*

Resilience as a term has as many definitions as people who talk about it. What if resiliency is treated as a concept? How do you measure a concept? In reviewing many definitions, "each [definition] … rests on one or two essential aspects of resilience: continuity and recovery in the face of change" (Zolli & Healy, 2012, p. 7). A key to the success of any resiliency analysis is to fully understand the level of protection and tolerance that is acceptable to meet mission needs and then to create a strategic plan accordingly. A true resilience measure is holistic, viewing the whole of a robust mission capability and not a sum of each component's capability.

Capitalizing on this holistic view, the resulting analysis compares and contrasts various capabilities with different conditions, requirements, and operations. Working within this tradespace, analysis may lead to critical junctures: Capability vs. Cost, Improvements vs. New Development, or Research and Development Investments vs. Sustainment. Knowing the State of Resiliency of a system will lead to answers to: How can resiliency be improved? Where should the next dollar go? And when has a system reached its end of life? This information can lead to informed decisions and better capabilities.

Effective resiliency planning comes from understanding situational and mission needs before a disastrous event occurs. Developing a Resiliency Tier Matrix would capture this situational and mission awareness. Resiliency Tiers demonstrate acceptable tolerance for the system/capability to meet mission needs. A goal in this entire process is to create a true holistic Resiliency Index that reflects more than each functional component's contribution.

## Hypothesis

The holistic analysis of resiliency provides insight into a capability or system's resilient characteristics and provides a means for creating informed decisions regarding funding, development, deployment, and mission accomplishment.

# Purpose

This article presents resiliency as a concept that incorporates many other factors and elements and develops a Resiliency Tier Matrix for analysis purposes.

# Scope

This article portrays resiliency as an overarching concept that affects capabilities and systems differently depending upon the situation. It develops a Resiliency Tier Matrix to provide a holistic view of what resilience means to that capability or system. The research was limited to recent articles on resiliency and various interpretations of resilience and its effects. The development of the Resiliency Tier Matrix involves the relationships between existing conditions and possible impacts to capabilities and systems. Use of the matrix provides decision makers with knowledge to make informed decisions. This article does not delve into resiliency associated with people or organizations because an abundance of literature already covers the many aspects of these two constructs.

# Discussion

The word resiliency has no universally accepted definition. Many organizations have coined more than one definition. One of the more accepted definitions is from the Office of the Secretary of Defense (Policy) (Department of Defense, 2012):

> The ability of an architecture to support the functions necessary for mission success with higher probability, shorter periods of reduced capability, and across a wider range of scenarios, conditions, and threats, in spite of hostile action or adverse conditions. Resilience may leverage cross-domain or alternative government, commercial, or international capabilities. (p. 12)

Resilience is an overarching concept or an umbrella, which encompasses many other concepts, characteristics, or parameters. Each may have a major impact at any one time. This leads to the basic question of how the resiliency of a capability can be improved. Many synergies and forces play important roles. Turning to systems, resiliency incorporates many other metrics and

variables. Figure 1 shows the various parameters and techniques associated with resiliency. As a concept, no single metric does resiliency sufficient justice. When defining a specific metric, another aspect of resiliency surfaces. The first metric no longer fits because the emphasis shifted to the next aspect or dimension.



FIGURE 1. RESILIENCY UMBRELLA

**ENVIRONMENT**
- Climate
- Cultural
- Economic
- Political
- Social
- Technology

**Mission System**

**AS DESIGNED/MODIFIED**
- Agility
- Availability
- Connectivity
- Dependability
- Disaggregation
- Diversity
- Engineering
- Fault Tolerance
- Modularity
- Robustness
- Simplicity/Complexity
- Survivability

**ADJUSTMENTS**
- Adaptation
- Counter Mechanism
- Decoupling
- Graceful Degradation
- Realignment
- Re-architecture
- Reconstitute
- Recovery

**MITIGATION ACTIONS**
- Change
- Contingency Planning
- Cooperation
- Connectivity
- Decoupling
- Dynamic Reorganization
- Evolution

Resiliency as a term applies to people, organizations, and items/systems. Information technology networks, ecological systems, social environments, and health conditions use the term. For each of these constructs, risks come from all directions: events, data operations, or even missions. Risks are generally more prevalent during events such as an adversarial attack or natural disaster or even from a series of minor incidents that add up. Preparation to meet these challenges would minimize exposure and provide faster reaction times. One means of minimizing effects would be to understand system vulnerabilities. Many of the ideas and concepts are taken from an IBM

paper on Business Resilience (IBM, 2009, p. 5). Even though the IBM article focuses on business and business management, a variation or derivation of its resiliency framework can be extended to systems and their environment.

The success of any assessment/estimation is situational awareness of all aspects of resiliency. It helps define the level of protection and tolerance that is acceptable. Appendix A describes a Resiliency Black Box and the interactions of the various parameters in Figure 1 under the Resiliency Umbrella. A strategic plan is needed to meet mission resiliency requirements. The implementation of such a plan comes with challenges: (a) assessing risk vs. cost – what level of vulnerability is tolerable? (b) viewing resilience as a strategic enabler, (c) developing a resilience culture, (d) assessing return on investment for resilience strategies (IBM, 2009, p. 7), and (e) linking capabilities to mission requirements. However, done correctly, the implementation could lead to informed decisions about tradespace and alternative actions beyond the technical solution.

Open literature discusses resiliency techniques. These seem to fall into three categories. The first category is human behavioral practices, social and societal impacts (The State of New York, 2013, p. 3), and application to systems-of-systems (Bodeau, Brtis, Graubart, & Salwen, 2013, p. 1). This category is outside the scope of this article. The second category illustrates approaches through case studies on how some communities increased their resilience within their environment. The third category provides an engineering framework for mapping goals to objectives to techniques. Figure 1 depicts many of these techniques, which lead into this Resiliency Tier development. The desired outcome is then to develop innovative measures to enhance resiliency similar to what the communities did in the second category.

In treating resiliency as a multidimensional concept, there needs to be a way to characterize it and still have some quantitative assessment. An analogy would be the status of a person's health, which is multidimensional. Numerous medical indices cover all aspects of health: temperature, weight, disease conditions, muscle tone, aging, etc. But when asked how healthy a person is, a general concept of what all the indices or parameters indicate is the appropriate answer. Resiliency can adopt the same construct. If resiliency of a system equates to the health of a person, then maybe there should be resiliency indices similar to health indices. Just like the health hazards that people experience, systems experience multiple attacks on their configurations. A specific health index addresses a specific health condition or set of related conditions. Depending upon the value and importance of the index, patients will spend their last dollar on a remedy. To obtain a cure,

patients need to learn the overall concept of their health. This is where assessment of the myriad of available health indices is invaluable in determining their state of health. Indeed, the decision may impact where patients choose to spend their health dollars. A similar analytical process can apply to systems or capabilities and their resiliency. The assessment of these various parameters or dimensions can determine a State of Resiliency and would lead to a holistic view of the system. This type of assessment informs budget, development, and/or deployment decisions.

There can be many indices describing resiliency, each emphasizing a different aspect. However, when asked how resilient a system or capability is, the answer should encompass the varied indications from the set of resiliency indices. If done correctly, this Resiliency Index would allow for comparisons of capabilities or systems within a tradespace. For purposes of this discussion, since the relationship between systems and capabilities is close, the rest of the article will concentrate on systems.

> *As a management tool, the Resiliency Tier Framework offers a way to compare various programs, systems, and capabilities in terms of potential tradespace, cost savings, or capability optimization.*

In reviewing literature, we found many articles that discussed metrics for resiliency. The Defense Science Board Task Force built a notional dashboard-metric collection system (DoD, 2013, p. 13). This system, having maturity levels and designed metrics, supported cyber systems at a very detailed level. In contrast, IBM developed a Resilience Tier Framework (IBM, 2009, p. 14). This framework defines levels of resilience to match business-driven requirements. It spans all business units, services, and technologies. It provides the client a streamlined direction for building a resilient architecture. Ultimately, a true resilience measure is holistic, encompassing the operations, technology, and culture of an organization. In a variation of the IBM model, the Resiliency Tier Matrix in this article has five Resiliency Tiers ranging from Tier I, which is a total disaster, to Tier V, which is the gold standard. In this case, 12 different indices are spread across the five tiers to assess the overall resiliency of a system.

Any military capability encounters numerous hazards or risks from all directions. Examples of sources for these risks are events, system failures, or human error. These risks can be minor or major depending upon

the conditions. To minimize the effects, system users need to be aware of vulnerabilities and have mitigating actions in place. Effective preparations and actions involve a holistic approach with proactive processes and vigilant situational awareness for the unknown (IBM, 2009, p. 5). When system users develop this holistic view, an extensive analysis compares and contrasts various capabilities, different conditions, environments, mission requirements, and operations. Armed with this view, decision makers can make informed decisions regarding better capabilities and their use.

The tool to help determine a system's State of Resiliency is the Resiliency Tier Matrix or Framework, with varying tiers of resiliency. Before proceeding further, an explanation of a Resiliency Tier Matrix or Framework and how it is built is appropriate. Consider the spectrum of resiliency divided into five states. This spectrum ranges from the worst state of resiliency—exposed—through the states of confused, aware, and operational to the best state: capable (Table 1). Appendix B, Table B1, presents further descriptions equating these states to mission accomplishment and operations.

| TABLE 1. RESILIENCY STATES VS. MISSION AND OPERATIONS | | |
|---|---|---|
| Exposed | No mission accomplishment | Ceases to function |
| Confused | Major mission impairment | Highly impeded |
| Aware | Minimal mission success | Minimal success |
| Operational | Effective mission success with difficulties | Effective |
| Capable | Mission success with no difficulties | Highly effective |

The question now arises: How is a system placed in one of these states? Measurable criteria (parameters, techniques, or metrics) help in constructing the matrix. The key criteria are those that help define this multidimensional concept. This set of criteria includes system characterization, operator confidence in the system, effectiveness of the security precautions, continuity of operations, and preparedness. Appendix B, Table B2, further explains these criteria. Each of these can further be subdivided depending on the interest and the importance of any parameter in Figure 1, Resiliency Umbrella. The matrix begins to take shape in Table 2.

The intent of this framework is to produce a more complete picture of the system and the forces pulling on resiliency. As mentioned earlier, what may be important one day may not be important the next. This is a way to set up a score card and evaluate the resiliency of a system. The weighting of the criteria would be set according to the priorities of those criteria. In addition this framework also provides a means of analyzing vulnerabilities, evaluating tradespace, and comparing various courses of action. Some benefits (IBM, 2009, p. 11) for constructing such a framework are:

- Aligning capability directly to mission;

- Projecting potential resiliency investments;

- Improving risk mitigation and planning; and

- Enhancing preemptive vs. reactive management.

Some key challenges (IBM, 2009, p. 7) for constructing such a framework are:

- **Viewing resiliency as a strategic enabler.** Resiliency has strategic importance. A resiliency strategy would be a single, integrated plan embraced and executed by all parts of the organization. It would focus on delivering mission capability. It would be the catalyst to higher levels of performance. Drawing together the different components, the overall result would be greater than the parts alone. Senior leadership should be committed to a single resiliency strategy. This strategy aligns with organizational goals to provide a holistic approach over mission-wide systems (McLaren, 2009).

- **Defining the value of mission resiliency.** "Mission resiliency encompasses a proactive approach that systematically prepares for potential disruption as opposed to waiting for a disruptive event to occur" (Peake, Underbrink, & Potter, 2012, p. 31). Understanding resiliency in the mission environment is a significant step in system development and security. A resilient mission system is more capable and more adaptable than the tools used against it. Its value is in less complexity and cost of securing mission systems. "The focus on mission resilience extends the scope of past security practices while simultaneously honing in on mission-critical systems, networks, and processes" (Peake et al., 2012, p. 29).

## TABLE 2. INITIAL FRAMEWORK FOR RESILIENCE

| Tiers Criteria | Priority Weighting | V [Capable] | IV [Operational] | III [Aware] | II [Confusion] | I [Exposed] |
|---|---|---|---|---|---|---|
| Scale | | 1 | 2 | 3 | 4 | 5 |
| System | | | | | | |
| Confidence | | | | | | |
| Security | | | | | | |
| Continuity of Operations | | | | | | |
| Preparedness | | | | | | |

- **Working with advanced technologies.** This provides the opportunity to assist in developing and integrating state-of-the-art solutions to meet time-critical needs. As an added benefit, it provides opportunities for proactive and independent research, analysis, testing, and prototype development to mission requirements.

- **Maintaining continuous availability of mission systems.** This type of system visibility leads to assuring uninterrupted availability of critical mission systems, without need for failover mechanisms or recovery operations.

- **Linking capabilities to mission requirements.** Building resilience into a system from the start requires an understanding of the mission, the environment, and potential risks. These systems are the capabilities that satisfy the mission requirements. Linking the capabilities and mission requirements and evaluating their effectiveness in a hostile environment should be done early in the life cycle of a program.

# Using Resiliency Tiers in Defining an Architectural Approach

Resiliency Tiers define levels of resiliency to match mission requirements. Resiliency Tiers span all domains, services, or technologies and provide insight for building a resilient architecture. The intent is that this Resiliency Tier Framework provides an objective scale for the classification of mission requirements. This scale is a set of consistent concepts, measurements, or criteria applied to mission systems or capabilities. This set links technical resiliency requirements to capabilities. Mission resiliency requires an architectural approach spanning the breadth of military and government capabilities. Resiliency Tiers (IBM, 2009, p. 10) help to classify mission requirements by:

- Defining a broad continuum of mission resiliency requirements that apply to all processes, services, development, and missions;

- Linking those requirements to a set of technology criteria that address all capabilities and resources in the mission environment; and

- Providing technical characteristics, criteria, and metrics to measure mission resiliency expectations, and to monitor and manage ongoing operations.

This process develops an effective holistic Resiliency Index. The whole is greater than the sum of each functional component's contribution. This index may also help in identifying how to maximize the architecture and optimize investment.

> *Mission resiliency requires an architectural approach spanning the breadth of military and government capabilities.*

## Benefits of Resiliency Tiers

Defining, developing, and maintaining Resiliency Tiers and associated resilient capabilities have a number of benefits (IBM, 2009, p. 11), such as:

- Better mission-to-technology alignment;

- Clear rationalization of investments in resilient capabilities;

- Greater opportunities for improvements to risk planning, strategy, and architecture;

- More prescriptive management of the mission environment to achieve system-wide resiliency;

- Assistance in gap analysis across mission, service, and technology domains;

- Help in bridging the communications and planning gaps for mission continuity resiliency and planning; and

- Integration of mission requirements with a system-wide approach to achieve greater affordability.

As a management tool, the Resiliency Tier Framework offers a way to compare various programs, systems, and capabilities in terms of potential tradespace, cost savings, or capability optimization.

## How Resiliency Tiers Are Used

The Resiliency Tier Framework supports every aspect of the mission system. In an analysis, this framework can address alignment of resiliency strategies with mission needs, can guide the mitigation of adverse actions, and can address all mission and system components.

These tiers are able to help conceptualize and align mission resiliency needs in multiple scenarios. Resiliency Tiers lead to a comprehensive picture of systems and vulnerabilities, and eventually an understanding of specific levels of service. Using this objective and quantitative approach, requirements definition and prioritization ensure that the resiliency objectives and acceptable costs are integral to the overall mission capability.

An organization can also use Resiliency Tiers for guidance to mitigate the potential or existing chaos caused by external forces. These tiers provide a framework for understanding the overall health of the mission area and systems. Similar to the IBM analysis, Resiliency Tiers can help reconcile mission resiliency requirements and guide the infrastructure requirements, architectural design decisions, and major initiatives that will be implemented to achieve the desired future resilient environment (IBM, 2009, p. 12).

Lastly, a tiered resiliency approach enables the warfighter to define a replicable and measurable framework that can address all mission components including weapon systems, force capabilities, and/or government actions (IBM, 2009, p. 13). It can provide a range of resiliency requirements as well as mitigating actions. In addition, the tiered resiliency approach may also apply to a wide range of government actions and resiliency mitigations such as diplomacy, technical redundancy, force structures, and economic measures.

## Five Tiers of Resiliency

This framework has five tiers for resiliency estimation (Table 2). Each tier serves as a set of guidelines that specifies the characteristics commensurate with each tier condition for each of five criteria: System, Confidence, Security, Continuity of Operations, and Preparedness. These criteria span the five Resiliency Tiers (defined as *Capable* [V], *Operational* [IV], *Aware* [III], *Confusion* [II], and *Exposed* [I]). When taken as a range, the Resiliency Tiers translate into a conceptual view of the resiliency status of the overall mission system.

The criteria may be any number of parameters or techniques, which are important at the time. Table 3 is a representative example of a populated Table. (Appendix B, Table B3 has more details in developing this matrix.) For instance, Preparedness is one of those criteria. The *Capable* Resiliency Tier defines Preparedness as having a holistic approach to resiliency; whereas the *Operational* Resiliency Tier classifies this as having specific plans in place to address resiliency. Depending on the mission resiliency requirements, either level might provide adequate preparedness; however, the *Capable* Resiliency Tier provides a complete strategy for addressing resiliency. The holistic strategy for the *Capable* Resiliency Tier reduces the effects of outside forces to planned courses of action and continuous vigilance, whereas the *Exposed* Resiliency Tier provides no indication of preparedness for a hostile environment. Again, depending on mission requirements, any level may provide adequate resiliency; however, the *Capable* Resiliency Tier provides for the most complete level of Preparedness for mission-critical functions. A similar analysis is possible with each Criteria or row.

The outcome of this assessment defines a set of immediate actions to improve the resiliency of mission systems. Some actions would result in the development of a longer term, strategic roadmap of major initiatives that would help meet mission expectations for future applications.

### Guidance on Scoring

When undertaking a resiliency assessment, the "how good" or "how bad" analysis addresses each criteria individually (National Patient Safety Agency, 2008, p. 14). This is a consequence of the mission environment. Consequence, in this context, means the condition or outcome of a mission capability in reaction to an outside force (National Patient Safety Agency, 2008, p. 4). Clearly, there may be more than one consequence for a single capability.

| TABLE 3. TABLE OF RESILIENCY TIERS | | | |
|---|---|---|---|
| **Tiers**<br>**Criteria** | **Priority Weighting** | **V**<br>**[Capable]** | **IV**<br>**[Operational]** |
| *Scale* | | *1* | *2* |
| SYSTEM — **Overview** | | Highly capable | Effective |
| **Normal Operations** | | Full capabilities on-line | Maintains normal operations, reached new equilibrium |
| **Protection** | | Protected | Protection measures in place |
| **Corrective Actions** | | Cohesive actions among all players | Synergy of actions among most actors |
| **Vulnerabilities** | | Potential vulnerabilities identified | Know of most vulnerabilities |
| **Planning** | | Holistic resilience strategy | Resiliency measures |
| **Mitigations** | | Attacks have little or no effect on operations | Successful in mitigating or avoiding most attacks |
| **Vigilance** | | Method to identify new vulnerabilities | Addresses obvious vulnerabilities |
| **Confidence** | | High | Moderate |
| **Security** | | High | Effective |
| **Continuity of Operations** | | Maximum | Able to operate effectively |
| **Preparedness** | | Holistic strategy approach | Specific plans in place |

**BEST** ←

| TABLE 3. TABLE OF RESILIENCY TIERS, CONTINUED | | |
|---|---|---|
| **III** | **II** | **I** |
| **[Aware]** | **[Confusion]** | **[Exposed]** |
| *3* | *4* | *5* |
| Minimum mission accomplished | Problems meeting any mission needs | Ineffective |
| Struggles to stay ahead of problems | Experiencing outages, delays, "blackouts," etc.—confused with anomalies | System failure, it crashes |
| Some protection available | "Band-aid" protection | No protection |
| Collaboration of effort to address issues | Attempting to resolve from within—disjointed actions | No clue what to do |
| Vulnerabilities exist | Few vulnerabilities known | Unaware of vulnerabilities |
| Realistic impact assessment | Minimal resiliency actions available | No resiliency designed in system |
| Some proactive measures in place | Reactive measures taken | No measures available |
| Aware of attacks | Can spell resiliency | Clueless |
| Medium | Low | Nonexistent |
| Appears to be adequate | Minimal with breaches | None |
| Barely meeting requirements | Failing | Complete breakdown |
| Minimal to acceptable | Insufficient | None |

**WORST**

Qualitative and quantitative techniques assess and score the consequences. Wherever possible, consequences should use objective definitions across different criteria within each tier to ensure consistency in the process. Despite defining each condition as objectively as possible, scoring the consequences will inevitably involve a degree of subjectivity. Figure 2 contains the flow diagram for the Resiliency Tier assessment.
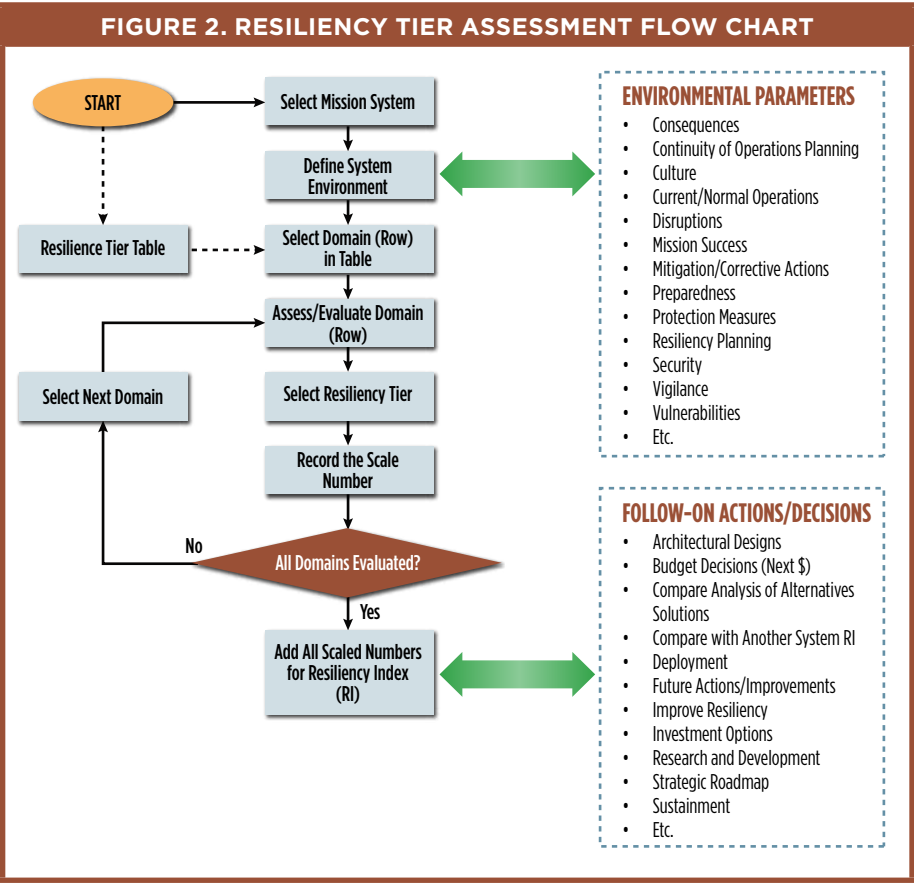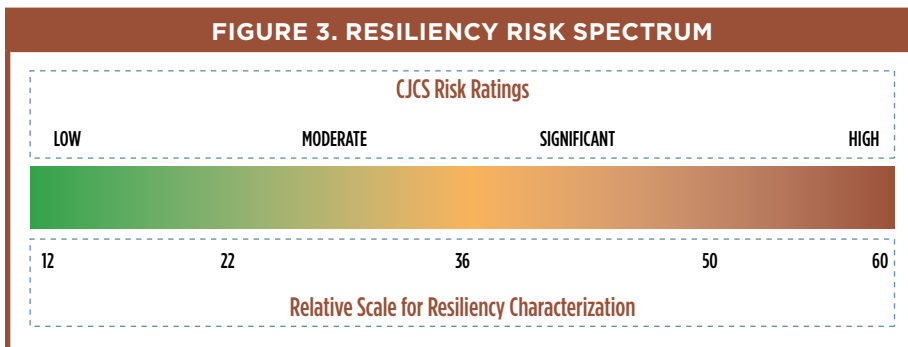


FIGURE 2. RESILIENCY TIER ASSESSMENT FLOW CHART

Table 3, Table of Resiliency Tiers, provides the framework to obtain an assessment of the State of Resiliency of a specific mission system. The process is:

- Select the mission system to review.

- Define explicitly the conditions (internally or externally) of the adverse consequences that are either encountered or might be encountered.

- Go to each row (criteria) in the table and identify the appropriate description, or tier, under the adverse condition. Appendix B contains further details for each term and description. Record the scale number at the top of each column. If a weighted value exists, multiply the scale number by the weighted value.

- Once all 12 rows are characterized, add all the scores based on the scale value (with or without weighted values) for each row. The total is the Resiliency Index.

- A variation to this table would be to change to another or different set of criteria or parameters. Add or delete a row. If one is added, establish the corresponding tier structure based on the new criteria. Keep modifications to a minimum. One of the benefits to having a set of criteria is the aspect of consistency in application.

This provides an overall resiliency assessment of the system: the greater the score, the lower the resiliency. The scores for this Resiliency Tier Framework (no weighting) would range from 12 (the best) to 60 (the worst). Putting these scores into perspective, compare them to the Chairman of the Joint Chiefs of Staff (CJCS) risk scale as part of the CJCS Resiliency Risk Spectrum (Figure 3).



**FIGURE 3. RESILIENCY RISK SPECTRUM**

CJCS Risk Ratings

| LOW | MODERATE | SIGNIFICANT | HIGH |

| 12 | 22 | 36 | 50 | 60 |

Relative Scale for Resiliency Characterization

The following is an example of how this Resiliency Tier Matrix is applied to a specific situation and system. Assume a large satellite terminal is located on foreign soil. The Status of Forces Agreement states physical protection is the responsibility of the host nation. Further, this terminal is vintage equipment nearing end of life. A local protest breaks out and the satellite signal is lost for the first time. After working with higher headquarters and taking approved mitigating actions, the maintenance crew restores the system to

**FIGURE 4. RESILIENCY ASSESSMENT EXAMPLE**

| Tiers / Domains | V [Capable] | IV [Operational] | III [Aware] | II [Confusion] | I [Exposed] |
|---|---|---|---|---|---|
| *Scale* | *1* | *2* | *3* | *4* | *5* |
| Overview | | | | ▓ | |
| Normal Operations | | | ▓ | | |
| Protection | | | | ▓ | |
| Corrective Actions | | ▓ | | | |
| Vulnerabilities | | | ▓ | | |
| Planning | | | | ▓ | |
| Mitigations | | ▓ | | | |
| Vigilance | | | ▓ | | |
| Confidence | | | ▓ | | |
| Security | | | ▓ | | |
| Continuity of Operations | | | ▓ | | |
| Preparedness | | | ▓ | | |
| **Index = 37 →** | 0 | 4 | 21 | 12 | 0 |

(Domains grouped under: SYSTEM)

full operational status within appropriate restoration time frames. Once all activities return to normal, the resiliency assessment (Figure 4) uses Table 3, highlighting the applicable tiers for each criteria within the Resiliency Tier Framework. Refer to Table 3 for the cell descriptions.

The sum of the respective scale numbers is 37. This number is displayed above the scale in Figure 5. An interpretation of this State of Resiliency would indicate:

- Increased system protection is imperative.

- Better planning for such events is necessary.

- Known vulnerabilities need more attention.

- The system is getting old.



FIGURE 5. RESILIENCY RISK SPECTRUM—STATE OF RESILIENCE
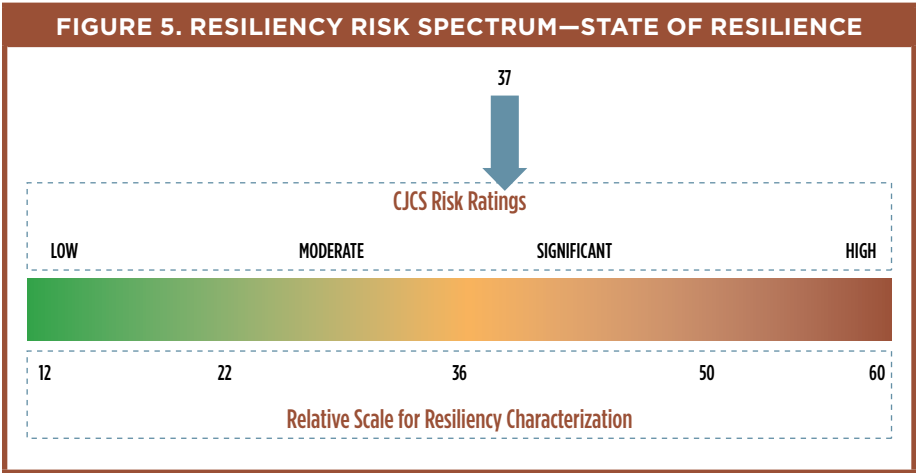
These four items would lead to a cost analysis of whether to upgrade or replace the system. They may also lead to a political discussion on the Status of Forces Agreement or whether or not the site should remain in its current location. Looking at a variation of the situation above where the terminal never goes down, discussions would be much different. Many of the cell evaluations in Figure 4 would move to the left.

This is a single application for illustration purposes; however, other options could be to maximize architectural designs, optimize investments, and differentiate resiliency between two systems supporting the same mission or among analysis of alternatives solutions. The analysis can be as rigorous as necessary with all details, a subset of details, or limited details depending on the purpose and desired outcome.

# Summary

The tiered approach to resiliency can aid in planning for adverse or intrusive events proactively. This helps maximize return on investment from assets, technology, and people at the time when needed most. Using Resiliency Tiers to develop effective long-term strategies ensures that shorter term tactical actions are properly aligned and supports a military capability progress along the resiliency maturity continuum. Investing in resiliency measures at the program start will help make sure that long-term resiliency investments preserve value over time.

# References

Black Box Model. (n.d.). *Investopedia* [Online investment dictionary]. Retrieved from http://www.investopedia.com/terms/b/blackbox.asp

Bodeau, D., Brtis, J., Graubart, R., & Salwen, J. (2013). *Resiliency techniques for systems-of-systems* (Report No. 13-3513). Bedford, MA: The MITRE Corporation.

Confidence, (n.d.). In *Oxford dictionaries* [Online dictionary].

Department of Defense. (2012). *Space policy* (DoDD 3100.10). Washington, DC: Office of the Secretary of Defense (Policy).

Department of Defense. (2013). *Task force report: Resilient military systems and the advanced cyber threat.* Washington, DC: Office of the Under Secretary of Defense for Acquisition, Technology and Logistics.

Holistic Strategy Approach. (n.d.). In *BusinessDictionary.com* [Online business dictionary]. Retrieved from http://www.businessdictionary.com/definition/

IBM Business Continuity and Resiliency Services. (2009). *Business resilience: The best defense is a good offense: Develop a best practices strategy using a tiered approach.* Somers, NY: Author.

Joint Chiefs of Staff. (2010). *Department of Defense dictionary of military and associated terms* (Joint Publication 1-02). Washington, DC: Author.

Joint Chiefs of Staff. (2011). *Joint operations* (Joint Publication 3-0). Washington, DC: Author.

McLaren, S. (2009). *EPMO: A strategic enabler?* [Discussion paper]. St. Kilda, Victoria, Australia: Dignus Group.

National Patient Safety Agency. (2008). *A risk matrix for risk managers.* National Health Service. London, England: Author.

Peake, C., Underbrink, A., & Potter, A. (2012, September/October). Cyber mission resilience mission assurance in the cyber ecosystem. *CrossTalk, 25*(5), 29–34.

Preparedness. (n.d.) In *Oxford dictionaries* [Online dictionary].

The State of New York. (2013). *Community resilience techniques.* New York: My Rising Communities.

The White House, Office of the Press Secretary. (2007). *Directive on national continuity policy* (Reports No. NSPD-51 & HSPD-20). Retrieved from http://policy.defense.gov/portals/11/Documents/hdasa/references/HSPD-20.pdf

Wang, W. (2009). *A hierarchical analysis of terrestrial ecosystem model Biome-BGC: Equilibrium analysis and model calibration* (Manuscript draft). Elsevier Editorial System™ for Ecological Modeling. Retrieved from http://ecocast.arc.nasa.gov/pubs/pdfs/2009/ECOMOD-S-08-00413.fdf

Zolli, A., & Healy, A. M. (2012). *Resilience: Why things bounce back.* New York, NY: Simon & Schuster.

# Appendix A

## Resiliency Black Box

In viewing the various parameters of Figure 1, Resiliency Umbrella, resiliency as a concept has many moving parts, elements, and metrics or components. At any one time, any of these can be a driving force for change. The result of that change could be a new equilibrium of interaction and collaboration. One way to visualize this interaction is to see resiliency as a black box. It has inputs (data, resources, and feedback) and has an output. In a more strict sense, a "black box" analysis "of [a] system contains formulas and calculations that the user does not see ... to use the system. Black box systems are often used to determine optimal trading practices [in investments]" (Black Box Model, n.d.). In this case, the Resiliency Black Box Model depicted in Figure A-1 illustrates how the various inputs—Adjustments, Mitigation Actions, and As Designed or Modified (internally) and Environment (externally)—when altered, can reach a new system equilibrium or resiliency state. Putting it another way, equilibrium ... refers to a steady status in which model state variables reach a dynamical balance (Wang, 2009, p. 9). This dynamic balance could result in a system achieving a reasonable, acceptable, or tolerable resiliency state. All the parameters contribute to the system equilibrium, whether new or a return to the previous state. The mission planner must assess the new resiliency state. If the resiliency state is unacceptable, a resiliency analysis needs to be accomplished to determine the best course of action that has a holistic effect on the system.



FIGURE A1. RESILIENCY "BLACK BOX" MODEL DIAGRAM
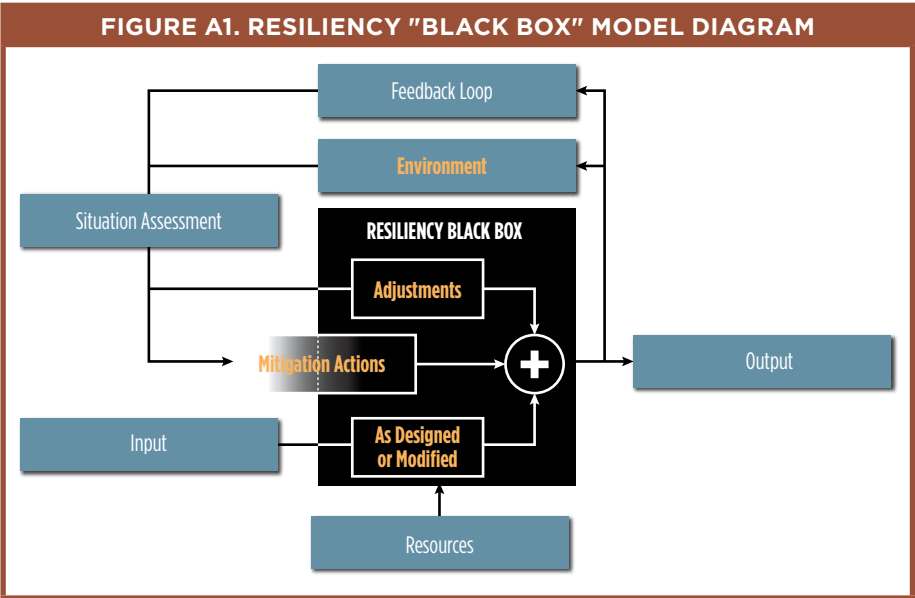
Generally, systems operate under two states: benign and hostile. The evaluation of these states occurs in the "Situation Assessment" block. Use the parameters, conditions, and/or metrics from Figure 1 to define and evaluate effectiveness. Pulling all of these together helps develop a Resiliency Index.

| TABLE A2. DESCRIPTION OF THE DOMAINS | |
|---|---|
| **Criteria** | **Description** |
| **Scale** | The measure of "how good" or "how bad" a system is relative to the Resiliency Tiers. |
| **System** | A functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements. (Joints Chiefs of Staff, 2011, p. GL-17) |
| **Confidence** | The feeling or belief that one can rely on someone or something; firm trust. (Oxford Dictionary, online reference) |
| **Security** | Measures taken by a military unit, activity, or installation to protect itself against all acts designed to, or which may, impair its effectiveness. (JP 1-02, page 226, 8 November 2010). |
| **Continuity of Operations** | The degree or state of being continuous in the conduct of functions, tasks, or duties necessary to accomplish a military action or mission in carrying out the national military strategy. (Joint Chiefs of Staff, 2010, p. 54) |
| **Preparedness** | A state of readiness, especially for war. (Oxford Dictionary, online reference) |

| TABLE A3. DESCRIPTION OF TABLE ELEMENTS | | | |
|---|---|---|---|
| **Criteria** | **Tier** | **Tier Description** | **Tier Explanation** |
| **Scale** | | 1-5 | This is an attempt to quantify the current condition of a system or capability. The lower the score the more resilient a system or capability is. |
| **SYSTEM** / **Overview** | V | Highly capable | System is highly capable of completing the mission. |
| | IV | Effective | System experiences some minor problems but effectively accomplishes the mission. |
| | III | Minimum mission accomplished | System is struggling to meet mission minimum requirements. |
| | II | Problems meeting any mission needs | System can't meet most mission requirements, is distracted by problems, and cannot keep up with mitigating actions. |
| | I | Ineffective | System cannot meet mission requirements. Problems have the system on the verge of collapsing. |
| **Normal Operations** | V | Full capabilities on-line | System is running all subsystems, processes and applications with no problems. |
| | IV | Maintains normal operations, reaches new equilibrium | System is running normal operations; however, it is continuously adjusting for disruptions. Each adjustment allows the system to reach a new equilibrium of operations. |
| | III | Struggles to stay ahead of problems | System cannot maintain mission accomplishment. It is struggling to stay ahead of the disruptions. Subsystems, processes, and applications are failing. |
| | II | Experiencing outages, delays, "blackouts," etc. —confused with anomalies | System is spending more time addressing disruptions than accomplishing the mission. The outages, delays, and disruptions are a distraction to the mission. Anomalies present no easy problems. |
| | I | System failure, it crashes | System crashes or is near to crashing under the weight of disruptions. |

| TABLE A3. DESCRIPTION OF TABLE ELEMENTS, CONTINUED | | | | |
|---|---|---|---|---|
| Criteria | | Tier | Tier Description | Tier Explanation |
| SYSTEM | Protection | V | Protected | System-wide protection has proactive processes in identifying and mitigating disruptions. System is alert to new disruptions and puts corrective measures in place immediately. |
| | | IV | Protection measures in place | System has many protective measures in place. It is not totally proactive in its corrective action. However, it is able to identify problems and react appropriately and swiftly. |
| | | III | Some protection available | System has elementary protection measures. Primary mode of correction is reactionary to disruptions. Little time is available to be proactive. |
| | | II | 'Band-Aid' protection | No system-wide protection in place. Disruptions circumvent any protection measures attempted. Fixes turn out to be band-aids addressing symptoms and not causes. |
| | | I | No protection | System has little or no protection at all. |
| | Corrective Actions | V | Cohesive actions among all players | When disruptions occur, there is a single focused team across the organization addressing any disruptions. |
| | | IV | Synergy of actions among most actors | Pockets of excellence pop up throughout the organization to address any disruptions. There is a coordinated synergy among all actions taken. The effectiveness of these actions is greater than the sum of the individual actions. |
| | | III | Collaboration of effort to address issues | There is a collaborative effort to address disruptions. This effort is initiated by the most affected subsystem or process or application. Coordination is not readily obtained. It takes time to address issues. |
| | | II | Attempting to resolve from within—disjointed actions | Individual offices work independent of each other in attempting to solve any issues. In some cases it is counterproductive. |
| | | I | No clue what to do | Little or no effort is put forward to address disruptions. |

| TABLE A3. DESCRIPTION OF TABLE ELEMENTS, CONTINUED | | | | |
|---|---|---|---|---|
| **Criteria** | **Tier** | **Tier Description** | **Tier Explanation** |
| **SYSTEM** | **Vulnerabilities** | V | Potential vulnerabilities identified | System is aware of all vulnerabilities, has a means of identifying new vulnerabilities, and is able to project vulnerabilities that result from new technology development. |
| | | IV | Know of most vulnerabilities | System knows of its primary vulnerabilities and can sense new vulnerabilities as they manifest themselves. System has an excellent means of assessing new technologies for possible impacts. |
| | | III | Vulnerabilities exist | System knows vulnerabilities exist; however, it is not aware of most of them. It reacts to disruptions. Has no ability to project vulnerabilities from new technology. |
| | | II | Few vulnerabilities known | System has the basic understanding of vulnerabilities and is aware of most. Has no effort in place to address new vulnerabilities ahead of disruptions. |
| | | I | Unaware of vulnerabilities | System's awareness of vulnerabilities is no more than elementary and probably much less. |
| | **Planning** | V | Holistic resilience strategy | System has a resilience strategy or Plan in place that is supported by the entire organization. It is ingrained in the architecture of the system and culture of the organization. It covers current conditions and future projected environments. It has provisions for training and education. |
| | | IV | Resiliency measures | System has a coherent set of resiliency measures that apply to any and every subsystem, capability or process. The concept is accepted organization wide; however, emphasis is different in different work centers or offices. |
| | | III | Realistic impact assessment | Realistic risk and operational assessments provide focused courses of action and necessary organizational involvement for current conditions. No long-term plan. |

| | | TABLE A3. DESCRIPTION OF TABLE ELEMENTS, CONTINUED | | |
|---|---|---|---|---|
| **Criteria** | | **Tier** | **Tier Description** | **Tier Explanation** |
| SYSTEM | Planning, continued | II | Minimal resiliency actions available | Any resiliency actions available are reactive and localized to specific subsystems, capabilities or processes. There is no effort to address issues at a system level. |
| | | I | No resiliency designed in system | Resiliency is taken for granted. There is no underlying theme or approach to Resiliency. |
| | Mitigation | V | Attacks have little or no effect on operations | Attacks are generally insignificant. System is able to tolerate and mitigate them and continue operations as normal. |
| | | IV | Successful in mitigating or avoiding most attacks | Attacks are annoying. Specific actions need to be taken; however, they are successful in mitigating any effects. |
| | | III | Some proactive measures in place | Attacks are serious and cannot be ignored. More reactive than proactive measures are necessary. Many consequences of attacks are unexpected. |
| | | II | Reactive measures taken | Attacks are critical to the system operation and mission accomplishment. The reactive measures do not handle all of the attacks. |
| | | I | No measures available | Attacks are catastrophic and result in system shutdown. |
| | Vigilance | V | Method to identify new vulnerabilities | System has means to research and assess new sources of disruptions and the vulnerabilities. It is generally expected that the system is prepared for new technology attacks. |
| | | IV | Addresses obvious vulnerabilities | System is in place to address all known vulnerabilities. The ability to address the surfacing of new vulnerabilities is a reactive, but effective, process. |
| | | III | Aware of attacks | System is aware of new vulnerabilities as they are attacked. It has no means of identifying the new vulnerabilities prior to an attack. |

| TABLE A3. DESCRIPTION OF TABLE ELEMENTS, CONTINUED | | | |
|---|---|---|---|
| **Criteria** | **Tier** | **Tier Description** | **Tier Explanation** |
| SYSTEM — Vigilance, Continued | II | Can spell resiliency [surprised by attacks] | System needs to take time to study an attack and the symptoms before it can generate the awareness of a new vulnerability. It may not be able to correct or mitigate the new vulnerability. |
| | I | Clueless [does not know what to do] | System seeks outside help because it does not understand the new vulnerability or the extent it affects the mission. |
| Confidence | V | High | System confidence is high, fully confident that the system or capability will perform the mission with little or no disruptions affecting operations. |
| | IV | Moderate | System has moderate confidence that it will accomplish the mission in spite of potential disruptions. |
| | III | Medium | Medium confidence illustrates concern over mission accomplishment and integrity of the system. |
| | II | Low | Low confidence lacks any belief that the system can be counted on to do the mission. |
| | I | Nonexistent | No confidence means that the system is not acceptable. |
| Security | V | High | There are no acts that can bypass or contravene security policies, practices, or procedures. |
| | IV | Effective | In an environment of minor security breaches, security policies, practices, or procedures are able to protect the system effectively for mission accomplishment. |
| | III | Appears to be adequate | On the surface, security policies, practices, or procedures appear to be effective; however, security problems exist and often prevail. |
| | II | Minimal with breaches | Security breaches dominate the system and create an environment of mistrust. This leads to minimal to no mission accomplishment |
| | I | None | There are no security policies, practices, or procedures in place to prevent breaches. |

# Appendix B

## Resiliency Tier Descriptions

| TABLE B1. DESCRIPTION OF THE FIVE TIERS | | |
|---|---|---|
| **Tier** | | **Description** |
| **V** | **Fully Capable** | May result in a slight perturbation in operations; however, the system/capability continues operating with nothing more than a "hiccup." Any disruption is an exceptional circumstance. (Insignificant disruptions) |
| **VI** | **Operational** | May experience a disruption resulting in possible resets or reboots; however, mission is accomplished and the disruptions are immediately isolated and mitigated. Disruptions can occur at any time; however, they are not showstoppers. (Negligible disruptions) |
| **III** | **Aware** | Is cognizant of operating environment, hazards therein, and vulnerabilities. Disruptions have a reasonable likelihood of occurring at any time. Mitigating actions are not always effective. Capability tolerates disruptions, but also does not handle the consequences well. (Moderate disruptions) |
| **II** | **Confusion** | Disruptions result in permanent partial disability or operational incapacity. Likelihood of disruptions happening is high. There is no requisite understanding of the problems. (Extensive disruptions) |
| **I** | **Exposed** | Disruptions are inevitable and greatly impact the system/capability. The capability is unprotected, totally exposed to hazardous environment. Damage may be irreversible. (Catastrophic disruptions) |

## Author Biography

**Col Dennis J. Rensel, USAF (Ret.),** is currently a senior space analyst with Booz Allen Hamilton, Inc., supporting the Office of the Secretary of Defense Cost Analysis Performance Evaluation (CAPE) Simulation Analysis Center (SAC). Prior to joining Booz Allen 12 years ago, he retired from the U.S. Air Force as a colonel following 25 years of military service. Col Rensel holds a JD from The Catholic University of America's Columbus School of Law; an MS in Electrical Engineering with a concentration in Electrical Engineering and Digital Systems from the Air Force Institute of Technology; and a BS in Electrical Engineering with a minor in Computer Science from the United States Air Force Academy.

*(E-mail address: dennis.j.rensel.ctr@mail.mil)*

# PERFORMANCE INDEXING:

## Assessing the **NONMONETIZED RETURNS ON INVESTMENT** in Military Equipment

*Ian D. MacLeod and Capt Robert A. Dinwoodie, USMC*

A prime managerial concern is how to decide which investment alternatives provide the greatest return with least risk of loss. In civilian organizations, numerous methods and formulas assist these decisions. However, in military and other governmental agencies, these methods often fall short because typical governmental investments do not have a monetary return. The processes underpinning governmental resource allocation and acquisition decisions are often cumbersome and time consuming. In this article, the authors present a unique application of composite indexing methods to compare the return on investment in military equipment. They posit that this analytical method can improve government agencies' investment decisions for capital equipment, especially when methods that are more laborious cannot be executed in the allotted time frame.

A prime managerial concern is how to select, among a range of investment alternatives, the option that provides the greatest return with least risk of loss. In civilian organizations, numerous methods and formulas such as Net Present Value, Return on Investment (ROI), and Return on Assets address these issues (Brealy, Myers, & Allen, 2011). However, in military and other governmental agencies, these methods often fall short because government investments do not offer a monetary return. Rather, they provide intangible returns such as national defense, public safety, goodwill, and other public goods that are difficult, but not impossible, to quantify (Oswalt et al., 2011). As Gonzalez, Perera, and Correa (2003) noted, "the economic valuation of nonmarket goods…is aimed at obtaining a monetary assessment of the welfare or utility gain (or loss) experienced by a certain group of people from the improvement of (or damage to) a nonfinancial asset" (p. 65).

Numerous economic models for calculating ROI exist, and most require only a few basic inputs such as costs, benefits, time horizon, and risks (Bailey, 2015). The benefit of calculating ROI of government investments is to save costs over other alternatives (Bailey, Mazzuchi, Sarkani, & Rico, 2014), but scholarly research into assessing the ROI of complete military systems is lacking. In this article, we present a method that efficiently compares equipment options using a composite index that generates a normalized measure of performance return. By objectively assessing equipment's ROI, leaders can eliminate low-value and inefficient programs, ultimately saving U.S. taxpayer dollars.

## Background and Literature Review

Department of Defense (DoD) budget and acquisition decisions are lengthy processes governed by hundreds of federal laws and practices (Chairman of the Joint Chiefs of Staff, 2015), often producing suboptimal and ineffective results (Government Accountability Office, 2008). Such decisions involve professionals from many government entities and disciplines, as well as politicians who all have different perspectives on the best way to invest scarce public funds. As decision analysts at Headquarters Marine Corps, we saw leadership request analytical support to make

considerable performance, capacity, and resource trade-offs quickly during all phases of the Planning, Programming, Budgeting, and Execution system cycle. Often, these decisions are made with an incomplete understanding of an investment's value (return) because it cannot be objectively quantified. To support resource allocation decisions, our mission was to provide accurate and timely analyses with readily available information.

In fiscal year 2014, the Marine Corps evaluated its strategic equipment investment initiatives for the ground combat and tactical vehicle (GCTV) fleet. Between 2025 and 2035, 85 percent of currently fielded platforms within the GCTV portfolio are projected to reach the end of their service life, necessitating a large influx of capital to replace or sustain GCTV capabilities (Dinwoodie, 2012). In addition, all these investments are competing for dwindling funds within the larger Marine Corps budget due to the 2011 Budget Control Act and predicted reductions in defense spending (Krepinevich, 2012; Liebman, 2013). Inevitably, declining budgets force trade-offs among important projects.

When we analyzed GCTV asset options, it was difficult to compare the costs and returns of different types of equipment as complete systems. As Oswalt et al. (2011) asserted, "a practice or methodology does not exist in the DoD to capture and characterize the future and extended value accruing to users beyond the primary recipients of the investment" (p. 126). Boiling complex military systems down to one metric is difficult for three main reasons: (a) vehicle performance measures typically cannot be aggregated into a single overall measure; (b) opinions about military equipment's utility differ and are often subjective; and (c) accepted quantitative methods for assessing overall value are time- and resource-intensive.

First, performance data on vehicles are typically measured and quantified in different units of measure for specific characteristics such as fuel consumption in miles per gallon; payload in pounds; and speed in miles per hour. Within the Joint Capabilities Integration and Development System (JCIDS), developing achievable requirements, called Key Performance Parameters (KPP)[1] and Key System Attributes (KSA),[2] requires establishing Measures of Performance (MOP) and Measures of Effectiveness (MOE). MOPs are "system-particular performance parameters such as speed, payload, range…or other distinctly

quantifiable performance features" (Defense Acquisition University, n.d., para. 1). MOEs measure operational capabilities in terms of engagement or battle outcomes (Department of the Air Force, 1996). Elaborate operational testing and evaluation events are created to evaluate these measures (Gentner, Best, & Cunningham, n.d.). Extensive modeling and simulation events evaluate system performance in scenarios and vignettes (Gentner et al., n.d.; Lai & Lamoureux, 2012; Lingel et al., 2012). While these methods assess performance and provide inputs to decisions, they are not structured to create a singular and objective measure of ROI. Performance metrics such as MOPs, MOEs, KPPs, and KSAs can be compared across systems, but cannot be aggregated into a single measure of overall performance without normalization.

Second, qualitative value assessments of military equipment are often subject to biases "because personal cognitive processes inform how individuals understand their environment" (Reynolds, 2015). Consequently, military personnel have different qualitative biases towards equipment based on their specific experiences (Simon, 2004). Conversely, the assessment of a financial investment's ROI is simpler: $\frac{Profit}{Cost}$

(Stickney, Weil, Schipper, & Francis, 2010) and normalized in a common measure: dollars.

Third, a significant body of research and accepted practices exists to quantitatively assess qualitative value preferences, but these methods are time- and resource-intensive. The Analytic Hierarchy Process (AHP) is a multilevel, decision-making framework that allows "practitioners to assign numerical values to what are abstract concepts and then deduce from these values

decisions to apply to a global framework" (Saaty, 1988, p. 110). This framework allows the judgments of qualified individuals to be aggregated into a group judgment. Based on the intensities of those judgments, an output with explicit rules for allocating resources among competing projects is derived (Saaty, 2013).

Similarly, Multiple-Objective Decision Analysis (MODA) and Value-Focused Thinking are interrelated methodologies that can derive value functions that map performance scores to value metrics (Parnell, Bresnick, Tani, & Johnson, 2013). MODA "quantitatively assesses the trade-offs between conflicting objectives by evaluating an alternative's contribution to the value measure and the importance of each value measure" (Parnell et al., 2013, p. 196). However, both AHP and MODA can be time consuming and difficult to execute since they typically require significant amounts of senior leadership attention (Triantaphyllou & Mann, 1995).

Given the shortcomings of more elaborate methods, our desire was to create a single ROI metric that provides a straightforward, quantitative, and objective evaluation of options. Our method utilizes a composite index to normalize different measures and aggregate them into a single metric facilitating holistic comparison of multiple system alternatives. In this case, we used established KPPs and KSAs, or Performance Metrics, as a baseline. We then calculated the relative deviation of multiple platforms' performance from this baseline. This method, called the Distance to Reference (DTR) technique, "measures the relative position of a given indicator vis-à-vis a reference point" (Organisation for Economic Co-Operation and Development, 2008, p. 28). The disparate measures are normalized by dividing the tested performance value's distance from the reference point by the reference point. Once all metrics are converted, they are aggregated into a single metric that quantifies the total performance of each alternative. The composite index is simply the performance measured from the reference standard. We call this metric a performance index (PI).

By creating a single measure of system performance rather than independently evaluating multiple systems' Performance Metrics, we directly compared different material solutions against each other and our reference standard simultaneously. We believe this analysis can assist other professional decision analysts, both in military and civilian fields, to improve the quality of actionable information provided to leadership. Further, the graphical displays we created easily communicate complex economic trade-offs among capital equipment options. To illustrate our method, we apply it to a case study on Marine Corps vehicles.

# Case Study

## Background

We began this analysis while conducting financial analytics and modeling for the 2014 Marine Corps GCTV strategy update (a 25-year capital investment plan). The Marine Corps was considering two investment courses of action (COA) to recapitalize its truck fleet with a mix of newly procured vehicles and sustainment programs for older platforms.

We will call the trucks in this fleet ALPHAs, BRAVOs, and CHARLIEs. The baseline COA consisted of a three-platform mix of approximately 20,000 vehicles. One-third would be next-generation BRAVOs; the next third would be an upgrade of newer existing ALPHAs; and the final third would be CHARLIEs undergoing minimal sustainment actions. This mixed fleet was institutionally preferred because it was believed to provide acceptable performance at lower cost due to the smaller quantity of BRAVOs (the most expensive vehicle). The Marine Corps was also considering a second COA that would eventually replace all ALPHAs and CHARLIEs with BRAVOs by 2040. This COA would initially fund ALPHAs and CHARLIEs, but eventually replace them, one for one, with BRAVOs.

By using our PI methodology, we found that the BRAVO significantly outperforms the ALPHA and CHARLIE in an absolute sense and additionally provides greater performance per dollar ($PP_\$$) when its PI is divided by the procurement cost. Additionally we wanted to explore whether other vehicle mixes could provide higher levels of truck fleet performance at lower cost, because funding constraints often prohibit purchasing desired quantities of exquisite systems. We used the PI to generate four additional COAs that showed higher return is achievable for less cost. The Marine Corps subsequently changed its truck procurement strategy partly because of our analysis.

## Assumptions

To facilitate our analysis, we made the following assumptions:

- BRAVO's performance represented the ideal performance benchmarks, because without financial constraints, the only vehicle acquired would be BRAVO.

- Performance Metric values had linear returns to scale.

- Performance Metrics are independent, allowing them to be summed together in a linear fashion.

- All Performance Metrics comprised equal value, or weight, relative to the vehicles' total performance.

## Research Questions

By generating a single ROI for each platform, we could do the following:

- RQ1: Compare platforms as complete systems, not just individual characteristics between systems (X vs. Y, not just the payload of X vs. the payload of Y).

- RQ2: Determine the average $PP_\$$ spent for each vehicle alternative and each vehicle mix COA.

- RQ3: Compared with the baseline COAs, create new ways to achieve equal or greater performance in the truck fleet at different funding levels as well as identify, quantify, and evaluate the risks in all COAs.

## Methodology

**Data, variables, and modeling.** We gathered institutionally approved life-cycle costs and performance data for all trucks. We conducted all our analysis, modeling, and additional COA development in Microsoft Excel.

**Defining Performance Metrics.** Table 1 shows the six notional primary Performance Metrics for all three trucks (T). AR1 and AR2 are quantitative measures of vehicle armor. Payload (D) is the vehicle's useful carrying capacity measured in pounds. Mobility (M) is an index value measuring the vehicle's ability to maneuver in soft soil. Reliability (R) is the mean miles between operational mission failures. Power generation (G) is the number of gallons per hour required to produce 20 kilowatts of electricity. For both M and G, a lower number is better. Because each Performance Metric is expressed in different units of measure, they cannot be combined into an aggregate score without normalization.

### TABLE 1. VEHICLE PLATFORMS, PERFORMANCE METRICS, AND VARIABLES

| | Armor 1 (AR1) | Armor 2 (AR2) | Payload (D) | Mobility (M) | Reliability (R) | Power Generation (G) | Total Platform Performance |
|---|---|---|---|---|---|---|---|
| **Optimal Performance** | **0.5** | **1.0** | **3500.0** | **25.0** | **2400.0** | **1.6** | **N/A** |
| Alpha (A) | 0.0 | 0.4 | 1500.0 | 30.0 | 1100.0 | 3.0 | N/A |
| Bravo (B) | 0.5 | 1.0 | 3500.0 | 25.0 | 2400.0 | 1.6 | N/A |
| Charlie (C) | 0.0 | 0.4 | -1155.0 | 36.0 | 170.0 | 3.0 | N/A |

**Normalizing Performance Metrics.** Because BRAVO's performance was the standard, we turned its Performance Metrics into the variable optimal, $O_i$, from which all deviations are assessed. Other applications of this methodology could choose a different $O_i$, such as acquisition threshold or the objective requirements for KPPs and KSAs. All three trucks' Performance Metrics are indexed against all six optimal Performance Metrics as a percentage deviation in actual performance.

The general equation for indexing each Performance Metric (PM) when a higher value is preferred was:

$$Indexed\ PM = \frac{Measured\ PM}{Optimal\ PM}\ X\ 100$$

For example, the optimal payload is 3,500 lb. The ALPHA payload is 1,500 lb. Therefore,

$$ALPHA\ Indexed\ D = (1500/3500) * 100 = 42$$

This shows that ALPHA delivers 42 percent of our optimized payload (D). For consistency, we needed to index mobility (M) and power generation (G) differently because a lower score for those metrics indicates better performance. To do this, we calculated the index so that a measured Performance Metric's percentage difference above the optimal value was an index score below 100.

The general equation for indexing each Performance Metric when a lower value indicates a better score is:

$$Indexed\ PM = \left( 2 - \frac{Measured\ PM}{Optimal\ PM} \right) \times 100$$

For example, the optimal (M) is 25 and ALPHA's M is 30. Therefore,

$$ALPHA\ Indexed\ M = \left(2 - \frac{30}{25}\right) \times 100 = 80$$

This shows that ALPHA delivers 80 percent of our optimal (M). Table 2 shows the indexed performance characteristics including the total performance of each platform. The total platform performance (TPP) column is the sum product of all indexed Performance Metrics.

**Scaling and weighting performance variables.** As stated in Table 2, TPP is an absolute measurement scale; as such, it is difficult to interpret and gauge the percentage difference between platforms. Scaling TPP to a 100-point scale increases the metric's understandability. Including the weights (W) of the indexed Performance Metrics allows their relative importance to

affect the TPP score according to organizational value. In this instance, we did not have institutional value assessments for the Performance Metrics and thus we let all variables carry an equal weight of 16.6 percent (100/6).

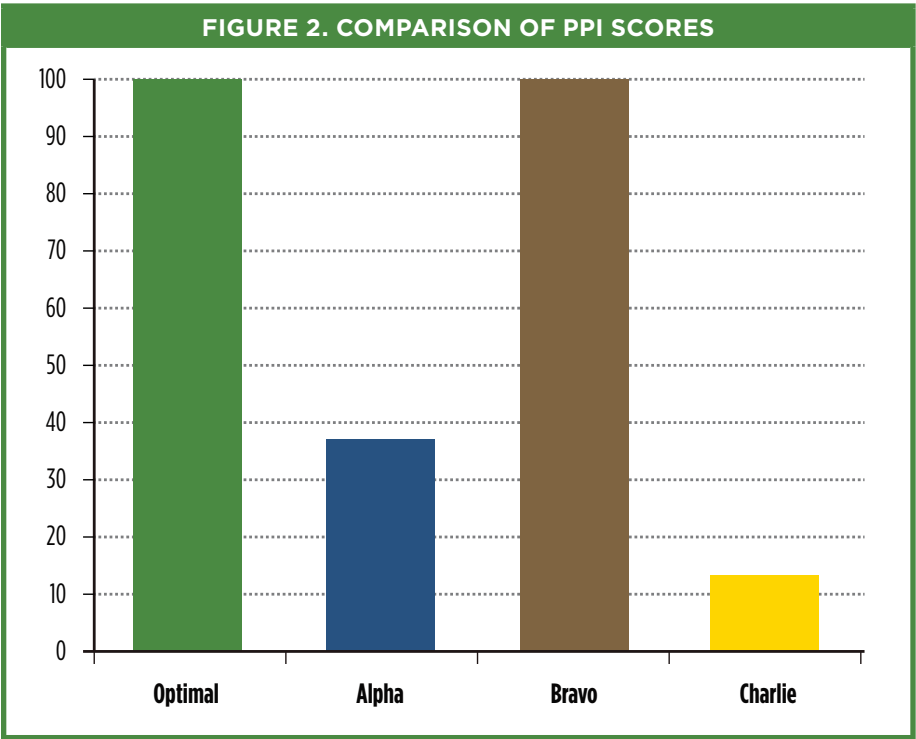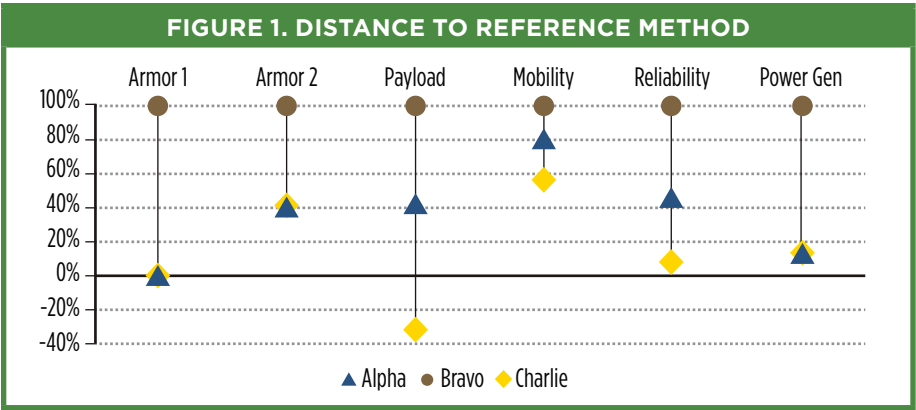| TABLE 2. INDEXED PERFORMANCE METRICS AND ABSOLUTE TOTAL PERFORMANCE | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Armor 1 (AR1) | Armor 2 (AR2) | Payload (D) | Mobility (M) | Reliability (R) | Power Generation (G) | Total Platform Performance |
| Optimal Performance | 100 | 100 | 100 | 100 | 100 | 100 | 600 |
| Alpha (A) | 0 | 40 | 43 | 80 | 46 | 13 | 222 |
| Bravo (B) | 100 | 100 | 100 | 100 | 100 | 100 | 600 |
| Charlie (C) | 0 | 40 | -33 | 56 | 7 | 13 | 83 |

The scaled TPP of each vehicle is the sum product of its indexed Performance Metrics. Using the equal Performance Metric weights (16.6 percent), the TTP equation is:

$$TPP = W_{FPU} * Indexed\ FPU + W_{FPW} * Indexed\ FPW + W_D * Indexed\ D + W_M * Indexed\ M + W_R * Indexed\ R + W_G * Indexed\ G$$

Table 3 shows the scaled and weighted TPP scores, while Figures 1 and 2 depict the DTR method and show how the scores are plotted. Figure 2 shows the TPP scores for the three alternatives against the optimal. It is important to note that the payload of Charlie, even with additional maintenance funding, returns less payload than required: this Performance Metric returns negative value and is not a computational error.

| TABLE 3. INDEXED AND SCALED PERFORMANCE METRICS | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Armor 1 (AR1) | Armor 2 (AR2) | Payload (D) | Mobility (M) | Reliability (R) | Power Generation (G) | Total Platform Performance |
| Optimal Performance | 17 | 17 | 17 | 17 | 17 | 17 | 100 |
| Alpha (A) | 0 | 7 | 7 | 13 | 8 | 2 | 37 |
| Bravo (B) | 17 | 17 | 17 | 17 | 17 | 17 | 100 |
| Charlie (C) | 0 | 7 | -6 | 9 | 1 | 2 | 14 |

## FIGURE 1. DISTANCE TO REFERENCE METHOD



## FIGURE 2. COMPARISON OF PPI SCORES



**Determining the truck fleet's cumulative performance return.** After deriving the TPPs for each platform, we calculated each COA's impact on truck-fleet performance by year, and over the entire investment horizon. Mathematically, this is vehicle quantity multiplied by TPP. Total cumulative performance is how much value a COA generates within the Marine Corps truck fleet.

We multiplied the projected yearly fleet mix inventory (I), which is the planned procurement quantity plus existing inventory, by $TPP_{A,B,C}$ to obtain a yearly COA Performance Point Score ($CPPS_Y$) for each year between 2015 and 2040. $CPPS_Y$ is the aggregate return of the entire truck fleet in one year. We then summed all the years to obtain a total score for each COA ($CPPS_T$). $CPPS_T$ represents how much total value each COA could provide across the entire investment horizon (2015–2040). The equations for $CCPS_{Y,T}$ are:

$$CPPS_y = \sum TPP_{A,B,C} * I_{A,B,C}$$

$$CPPS_t = \sum CPPS_{y_{i2015\text{-}2040}}$$

**Determining cost.** To develop total cost, we multiplied the yearly inventory (I) for all platforms $I_{A,B,C}$ by the projected maintenance and procurement actions in a given year. We then calculated the yearly costs ($C_y$) and total costs ($C_T$) for each COA. Table 4 lists the variables, factors, and costs associated with the truck fleet. All costs are in thousands of calendar year 2014 dollars. The "New" column shows the cost of procuring a single BRAVO and/or ALPHA. The columns for "SLEP" (Service Life Extension Program) show the cost of conducting a major overhaul of the CHARLIE fleet and the percentage of $I_A$ overhauled each year. The columns under "IROAN" (Inspect or Repair Only as Needed) show the estimated cost and percentage of each fleet scheduled for IROAN maintenance actions each year.[3] $C_N$ is multiplied by the yearly acquisition quantities. For brevity, Table 5 lists only the beginning and final acquisition quantities.

| TABLE 4. VARIABLES, COSTS, AND FACTORS | | | | | |
|---|---|---|---|---|---|
| | **Buy New (N)** | **SLEP (S)** | | **IROAN (IR)** | |
| **CY14$K** | **Cost** $(C_N)$ | **Cost** $(C_S)$ | **% of Inventory/ Year** $(I_S)$ | **Cost** $(C_{IR})$ | **% of Inventory/ Year** $(I_{IR})$ |
| Alpha | $175 | — | — | $86 | 5% |
| Bravo | $435 | — | — | $115 | 5% |
| Charlie | — | $147 | 5% | $100 | 10% |

The platform cost equations for BRAVO and ALPHA are:

$$Bravo\ C_y = \sum(C_N * B_{Qty}) + (C_{IR} * I_{IR})$$

$$Alpha\ C_y = \sum(C_N * A_{Qty}) + (C_{IR} * I_{IR})$$

| TABLE 5. TOTAL COST FOR COURSES OF ACTION: 2015–2020 ||
|---|---|
| **COA** | **Total Cost (FY14$B)** |
| 1 | $7.10 |
| 2 | $11.90 |
| 3 | $6.90 |
| 4 | $8.30 |
| 5 | $4.70 |
| 6 | $10.20 |

The platform cost equation for CHARLIE, which does not have any new procurement, is:

$$Charlie\ C_y = \sum (C_S * I_S) + (C_{IR} * I_{IR})$$

The total cost ($C_T$) for a COA is:

$$C_T = \sum_{n=2015\text{-}2040} C_{y_{A,B,C}}$$

Table 6 shows the total cost for each COA from 2016 to 2040.

| TABLE 6. TRUCK FLEET INVESTMENT COAS ||||||||||
|---|---|---|---|---|---|---|---|---|---|
| | **COA** | **COA Description** | **Alpha QTY** | | **Bravo QTY** | | **Charlie QTY** | | **Total** |
| | | | **2016** | **2040** | **2016** | **2040** | **2016** | **2040** | **2040** |
| **Baseline** | 1 | Mixed Fleet | 1325 | 6851 | 650 | 5500 | 16350 | 5421 | 17772 |
| | 2 | Max Alpha/Max Bravo | 1325 | 0 | 97 | 17772 | 16350 | 1972 | 17772 |
| **PA&E Created** | 2 | No Bravo (Null) | 1325 | 6851 | 0 | 0 | 16447 | 10921 | 17772 |
| | 4 | Cancel Alpha, Divert Funds to Bravo | 0 | 0 | 650 | 7121 | 17122 | 10651 | 20242 |
| | 5 | Cancel Alpha & Charlie, Buy More Bravo | 0 | 0 | 650 | 7121 | 17122 | 1473 | 17772 |
| | 6 | Cancel Alpha & Charlie, Buy Full Bravo | 0 | 0 | 2173 | 17772 | 18468 | 1473 | 17772 |

**Calculating PP$_\$$.** The $C_T$ of a COA is the sum of all procurement and depot-level sustainment actions from 2015 to 2040. To create a normalized return per dollar spent for each COA, we divided $CCPS_T$ by $C_T$. We call this metric performance points per dollar, $PP_\$$. This provides a normalized measure of the performance return for each dollar spent on a truck and the entire fleet capability. A higher value is better than a lower one because it indicates greater performance for less money.

The PP$_\$$ equation for a COA and individual truck is:

$$COA\ Return = PP_{\$C} = \frac{CPPS_{t_{1\text{-}6}}}{C_{T_{1\text{-}6}}}$$

$$Truck\ Return = PP_{\$T} = \frac{TPP}{Average\ Procurement\ Unit\ Cost\ (APUC)}$$

# Analysis

## Truck Investment COAs

We began the analysis with only two COAs in the truck portfolio. However, we created four additional COAs to evaluate cost and performance changes by varying fleet-mix (see Table 6). Specifically, we constructed a null COA to assess the truck fleet's value without BRAVOs and three additional COAs to explore the potential trade-offs among the other alternatives. The primary factor driving new COA development was leadership's desire to understand how many more BRAVOs could be bought if funding planned for ALPHAs and CHARLIEs was redirected to BRAVO procurement instead.

## Findings

By using our method, we evaluated our three research questions.

For RQ1, we found that the TPPs are as follows:

1. $TPP_B = 100$

2. $TPP_A = 37$

3. $TPP_C = 14$

ALPHA is only one-third as capable as BRAVO. CHARLIE is only one-seventh as capable.

For RQ2, by dividing TPPs by APUC (Average Procurement Unit Cost)[4] and SLEP costs listed in Table 4, we calculated their performance points per (thousand) dollars:

*BRAVO PP*$_\$$=1.38

*ALPHA PP*$_\$$=1.27

*CHARLIE PP*$_\$$=0.56

These metrics imply that every thousand dollars spent on the BRAVO returns approximately 1.38 performance points; on the ALPHA, 1.27; and on the CHARLIE, 0.56. In this example, spending money on ALPHAs or CHARLIEs does not offer the highest return. Funding should thus be spent on BRAVOs instead. However, this analysis also showed that even though overall ALPHA performance is less than that of BRAVOs, its low $APUC_A$ relative to $APUC_B$, allows for the creation of a COA with a similar level of $PP_\$$ at less cost.

We also compared the sensitivity of $PP_\$$ to changes in the APUC. We found that when the APUC for ALPHA falls below $160,200, a BRAVO no longer offers the highest return per dollar. Figure 3 shows the performance and cost curves for BRAVO and ALPHA. These curves identify the change in $PP_\$$ relative to the APUC as well as the inflection points where changes in the APUC reverse our previously stated best-value assessment. The Y-axis is TPP per $1,000 and the X-axis is a range of APUCs. BRAVO's performance is superior in absolute terms, but $PP_\$$ is sensitive to differences in unit cost. The current unit cost estimates for ALPHAs and BRAVOs are roughly proportional to their relative absolute performance levels, explaining why the $PP_\$$ is close between the options. However, changes in those unit cost estimates would change the $PP_\$$ even if absolute performance does not change.



**FIGURE 3. PERFORMANCE AND COST CURVES FOR BRAVO AND ALPHA**
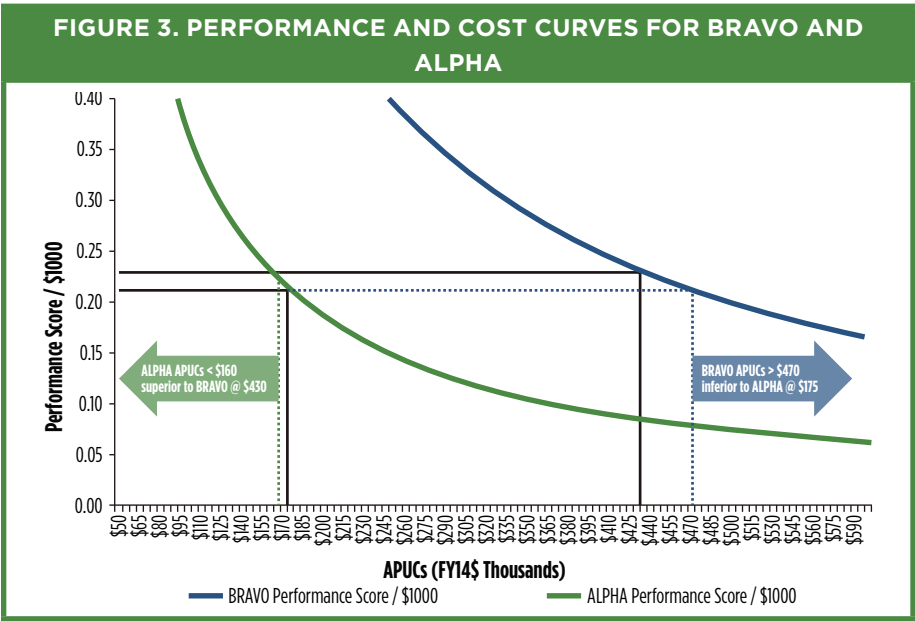
Holding all other variables constant, we can also see that the BRAVO would not offer highest $PP_\$$ if $APUC_B$ exceeds \$474,400. A rise of \$39,400, or 9 percent, in $APUC_B$, makes the ALPHA a better alternative per dollar. The change in $PP_\$$ due to change in $APUC_B$, is shown below:

$BRAVO\ PP_\$ = 1.26$

$ALPHA\ PP_\$ = 1.27$

Conversely, if $APUC_B$ is held constant at \$435,000, the APUC for the ALPHA must drop by approximately 8 percent to \$160,200 for it to become the better option in terms of $PP_\$$.

Finally, for RQ3, we evaluated all COAs' performance in four ways: (a) performance return each year from 2015 to 2040, $CPPS_Y$; (b) performance levels of each COA, $CPPS_T$; (c) cost of each COA, $C_T$; and (d) average trade-off between COAs, $PP_\$$ (see Table 7). This absolute scale shows the magnitudes of differences between the COAs in terms of cost and performance return. For example, we can see that COA6 provides twice the total performance of COA3 for an additional \$3.3 billion.

Figure 4 illustrates the information presented in Table 7. The X axis shows the total performance points over the investment period; the Y axis shows the total cost of each COA in billions of constant year 2014 dollars from 2015 to 2040; and the size of each bubble indicates the $PP_\$$.
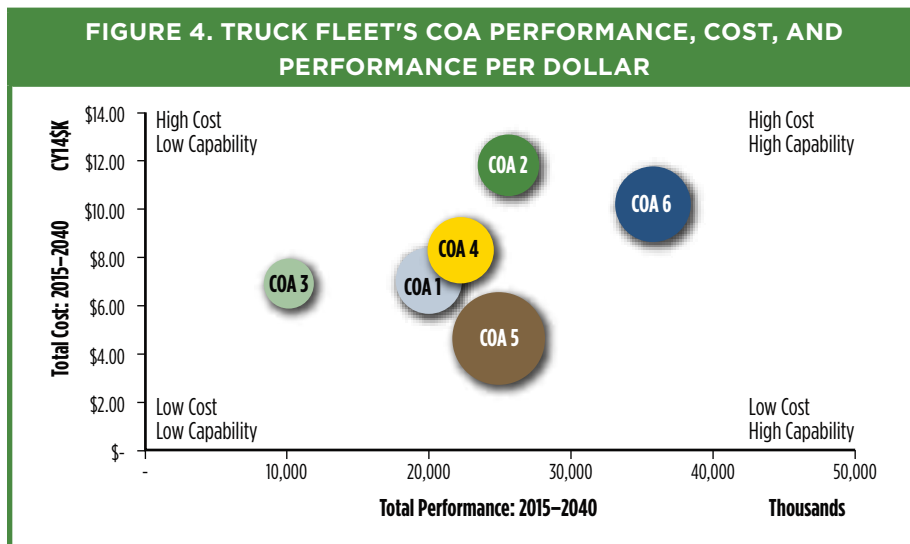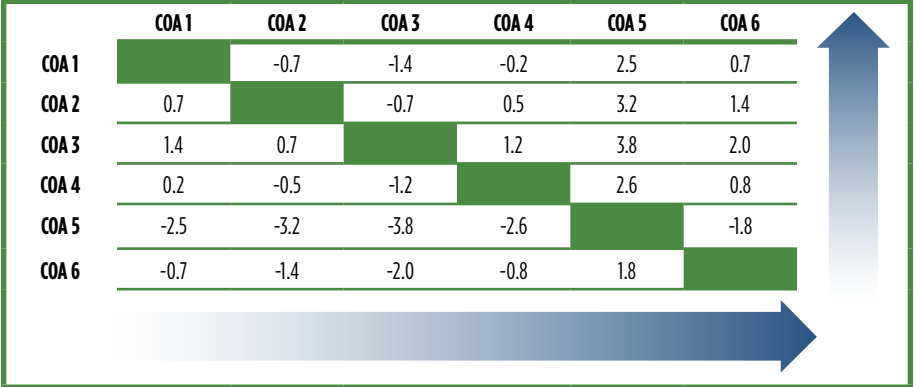


FIGURE 4. TRUCK FLEET'S COA PERFORMANCE, COST, AND PERFORMANCE PER DOLLAR

| TABLE 7. TRUCK FLEET COAS' COST AND PERFORMANCE | | | |
|---|---|---|---|
| COA | Total Cost ($C_T$) (FY14$B) | Cumulative Performance Points Total ($CCPS_T$) | Performance Points per Dollar ($PP_\$$) |
| 1 | $7.10 | 20,069,918 | 2.83 |
| 2 | $11.90 | 25,386,519 | 2.14 |
| 3 | $6.90 | 10,260,405 | 1.48 |
| 4 | $8.30 | 22,130,037 | 2.68 |
| 5 | $4.70 | 24,925,012 | 5.33 |
| 6 | $10.20 | 35,637,929 | 3.50 |

Using this figure to evaluate the COAs in our example quickly leads to the elimination of COA1–4, because COA5 and 6 have either greater capability or lower cost and greater capability. This presents leadership with a choice of maximizing performance overall (COA6) or maximizing $PP_\$$ (COA5). An efficient leadership decision is thus between the value of the extra capability and the opportunity cost of attaining it.

Figure 5 shows the change in average $PP_\$$ incurred by moving among alternatives. For instance, moving a dollar from COA4 to COA2 buys 0.5 fewer performance points than keeping that dollar in COA4. Conversely, moving a dollar from COA2 to COA4 buys 0.5 more performance points. Overall, COA5 is the best, as moving from COA5 to any alternative reduces the average $PP_\$$. In addition, moving from COA6 to any other COA except COA5 reduces the net benefit. Hence, COA5 and 6 should be the focus of leadership's decision making, and the original COAs (COA1 and 2) should be abandoned.

| FIGURE 5. PERFORMANCE TRADEOFFS BETWEEN TRUCK COAS | | | | | | |
|---|---|---|---|---|---|---|
| | COA 1 | COA 2 | COA 3 | COA 4 | COA 5 | COA 6 |
| COA 1 | | -0.7 | -1.4 | -0.2 | 2.5 | 0.7 |
| COA 2 | 0.7 | | -0.7 | 0.5 | 3.2 | 1.4 |
| COA 3 | 1.4 | 0.7 | | 1.2 | 3.8 | 2.0 |
| COA 4 | 0.2 | -0.5 | -1.2 | | 2.6 | 0.8 |
| COA 5 | -2.5 | -3.2 | -3.8 | -2.6 | | -1.8 |
| COA 6 | -0.7 | -1.4 | -2.0 | -0.8 | 1.8 | |

The timing of major investment decisions is another important factor to consider. Our methodology can be used to evaluate performance over time. Figure 6 plots the $CPPS_Y$ of COA1–6 from 2016 to 2040. This graphical representation shows each COA's benefit stream per year, throughout the investment horizon. Several options provide more performance earlier, and at less cost than the current baseline plan.



FIGURE 6. TRUCK FLEET COAS' PERFORMANCE BY YEAR
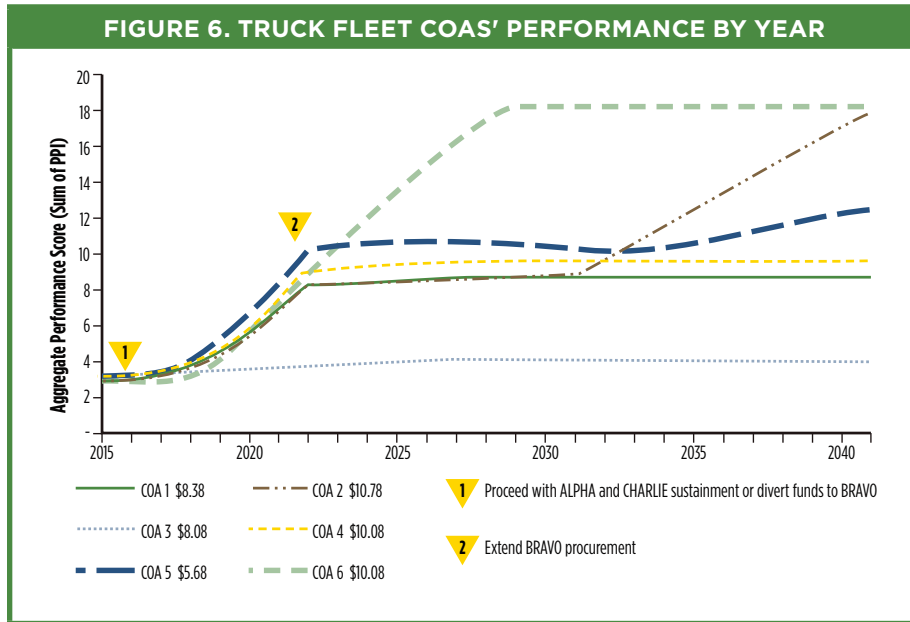
Decision point 1 shows where leadership should abandon COA1–4. Decision point 2 shows when a choice between COA5 and 6 should be made. This graphic highlights when major decisions are required before reductions in capability may appear and focuses discussions on risks, trade-offs, and mitigation plans across the time horizon. Leaders can assess differences in each COA's performance by year, over time, and against total cost. Aggregate cost and fleet performance trade-offs can be evaluated simultaneously.

# Additional Applications of the Methodology

### Source Selection Decisions

Using the PI method during formal source-selection decisions could allow all potential platforms under consideration to be normalized and evaluated objectively with (a) a common performance scale, and (b) a single metric based on each platform's ROI relative to performance standards. $PP_{\$}$ shows each system's monetized performance return and stream of benefits over time, allowing for direct comparisons against all competitors. In addition, as we have shown, this methodology defines the APUC range within which a given system is the preferred option in terms of $PP_{\$}$. The PI method can also facilitate objective strategic discussions about how different systems affect the projected fleet's performance.

This methodology is not solely limited to the DoD or military acquisition process. Any entity that makes capital investments that do not produce a monetized return could use it to compare alternatives objectively. For example, municipal governments and public safety agencies procuring emergency equipment could benefit from using this methodology, especially if there is not a formally defined or rigorous acquisition process and leaders simply want to know if they are getting "the most bang for the buck." The basic requirement is to understand the desired goals, objectives, and performance. If an investment has required performance standards, each alternative's deviation from that standard is straightforward and easily calculated using common software.

# Limitations of the Methodology

As presented, the method has several areas for improvement. First, the assumption of linear returns to scale possibly overstates the scores for each platform. However, this effect can be mitigated by including weights that reflect institutional value functions. MODA and AHP are effective methods to develop institutional value functions on each Performance Metric for inclusion in the PI calculation. In addition, the weights of each Performance Metric should accurately reflect their value contribution to the system's total performance.

# Conclusions

We used disparate performance measures to calculate a composite PI—an ROI proxy— to analyze the nonmonetized return of three trucks. We then evaluated two institutionally directed COAs for truck procurement and developed additional COAs with different cost and performance trade-offs. We found that the existing COAs provide less performance for more cost than the alternatives. A COA we created represented the most efficient use of fiscal resources since it provided the second highest level of performance at almost half the cost of the other COAs. This analysis shows that the Marine Corps can return more performance for each dollar spent. We recommended that the Marine Corps reevaluate its truck fleet options and consider alternative COAs. Based in part on this analysis, the Marine Corps shifted procurement plans in the GCTV fleet.

> *This PI method is objective: it is simply a reflection of institutional requirements and tested system performance.*

This method also has broad analytical applicability. First, the power of this method lies in its ability to aggregate disparate performance measurements into a common scale. This PI method is objective: it is simply a reflection of institutional requirements and tested system performance. By removing subjective bias, equipment investment decisions can focus on salient issues (e.g., cost, performance) rather than the different value perceptions among stakeholders. Second, as an ROI metric, the PI highlights areas of opportunity and loss. Options that inefficiently spend funding can be eliminated early, allowing subsequent analytical efforts to focus on alternatives returning highest institutional value. This improves decision quality and speed. Finally, using the PI method and graphics in this article, complex economic, cost, and performance information can be modeled quickly, supporting changing strategies. Altering variables (e.g., cost, vehicle mix, time) allows leaders to see the impacts their ideas have on fleet cost and performance, and assess the associated risks. All these factors lead to the PI method as an effective way to determine the ROI of nonmonetized investments.

# References

Bailey, R. F., Mazzuchi, T. A., Sarkani, S., & Rico, D. F. (2014, October). A comparative analysis of the value of technology readiness assessments. *Defense Acquisition Research Journal, 21*(4), 826–852. Retrieved from http://dau.dodlive. mil/2014/11/13/a-comparative-analysis-of-the-value-of-technology-readiness-assessments

Bailey, R. U. (2015). *A risk analysis tool for evaluating ROI of TRA for major defense acquisition programs* (Doctoral dissertation). Retrieved from ProQuest at http:// gradworks.umi.com/36/68/3668434.html. (UMI Dissertation Publishing No. 3668434)

Brealy, R. A., Myers, S. C., & Allen, F. (2011). *Principles of corporate finance.* New York, NY: McGraw-Hill.

Chairman of the Joint Chiefs of Staff. (2015). *Joint capabilities integration and development system (JCIDS)* (CJCSI 3170.01I). Retrieved from http://acqnotes. com/wp-content/uploads/2014/09/CJCS-Instruction-3170-01I-Joint-Capabilities-Integration-and-Development-System-23-Jan-15.pdf

Defense Acquistion University. (n.d.). *Glossary of defense acquisition acronyms and terms* [Online glossary]. Retrieved from https://dap.dau.mil/glossary/Pages/2237.aspx

Department of the Air Force. (1996). *Developmental test and evaluation* (AFI 99-101). Washington, DC: Secretary of the Air Force.

Dinwoodie, R. (2012). *Ground combat & tactical vehicle lifecycle crisis* [Unpublished internal analysis]. Washington, DC: Headquarters Marine Corps.

Gentner, F. C., Best, P. S., & Cunningham, P. H. (n.d.). *Sources of measures of effectiveness (MOEs) for assessing human performance in aeronautical systems.* Crew System Ergonomics Information Analysis Center (CSERIAC). Retrieved from http://www.ijoa.org/imta96/paper21.html

Gonzalez, S. G., Perera, A. G., & Correa, F. A. (2003). A new approach to the valuation pf production investments with environmental effects. *International Journal of Operations and Production Management, 23*(1), 62–82.

Government Accountability Office. (2008). *Defense acquisitions: Assessments of selected weapon programs* (Report No. GAO-08-467SP). Retrieved from http://www.gao.gov/products/GAO-08-467SP

Hagan, G. (2009). *Glossary of defense acquisition acronyms and terms* (13th ed.). Retrieved from https://dap.dau.mil/glossary/Pages/Default.aspx

Krepinevich, A. F. (2012, November–December). Strategy in a time of austerity: Why the Pentagon should focus on assuring access. *Foreign Affairs, 91*(6), 58–69.

Lai, G., & Lamoureux, T. (2012). *Development of measures of effectiveness and performance from cognitive work analysis products.* CAE Professional Services. Retrieved from http://www.dtic.mil/dtic/tr/fulltext/u2/a601721.pdf

Liebman, J. B. (2013). The deterioration in the U.S. fiscal outlook, 2001–2010. In J. R. Brown (Ed.), *Tax Policy and the Economy,* Vol. 27 (pp. 1–18).

Lingel, S., Menthe, L., Alkire, B., Gibson, J., Grossman, S., Guffey, R., …Wu, E. (2012). *Methodologies for analyzing remotely piloted aircraft in future roles and missions.* Santa Monica, CA: RAND.

Organisation for Economic Co-Operation and Development. (2008). *Handbook on constructing composite indicators: Methodology and users guide.* Paris, France: Author.

Oswalt, I., Cooley, T., Waite, W., Waite, E., Gordon, S., Severinghaus, R., Feinberg, J., & Lightner, G. (2011, April). Calculating return on investment for U.S Department of Defense modeling and simulation. *Defense Acquisition Reseach Journal, 18*(2), 121–143.  Retrieved from http://www.dau.mil/publications/DefenseARJ/Pages/Archives/arj58.aspx

Parnell, G. S., Bresnick, T. A., Tani, S. N., & Johnson, E. R. (2013). *Handbook of decision analysis.* Hoboken, NJ: Wiley and Sons.

Reynolds, P. (2015). Past failures and future problems: The psychology of irregular war. *Small Wars and Insurgencies, 26*(3), 446–458. (doi:10.1080/09592318.2013.866426)

Saaty, T. L. (1988). What is the analytical hierarchy process? *Mathematical Models for Decision Support, 48,* 109–121. (doi:10.1007/978-3-642-83555-1_5)

Saaty, T. L. (2013). The modern science of multicriteria decision making and its practical applications: The AHP/ANP approach. *Operations Research, 61*(5), 1101–1118.

Simon, C. J. (2004). *A case study of jumping from the C-17 and the C-130: A better platform for paratroopers?* Retrieved from http://www.dtic.mil/dtic/tr/fulltext/u2/a455930.pdf

Stickney, C. P., Weil, R. L., Schipper, K., & Francis, J. (2010). *Financial accounting: An introduction to concepts, methods, and uses* (Vol. 13). Mason, OH: South-Western Cengage Learning.

Triantaphyllou, E., & Mann, S. H. (1995). Using the analytic hierarchy process for decision making in engineering applications: Some challenges. *International Journal of Industrial Engineering: Applications and Practice, 2*(1), 35–44.

# Endnotes

[1] "Key Performance Parameters (KPP) are those attributes or characteristics of a system that are considered critical or essential to the development of an effective military capability and that make a significant contribution to the characteristics of the future joint force. A KPP normally has a threshold representing the minimum acceptable value achievable at low-to-moderate risk and an objective representing the desired operational goal, but at higher risk in cost, schedule, and performance" (Hagan, 2009, p. B-100).

[2] "Key System Attributes (KSA) are the attributes considered most critical or essential for an effective military capability, but not selected as Key Performance Parameters (KPP)" (Hagan, 2009, p. B-101).

[3] "A service life extension program or SLEP is a major overhaul of a vehicle that incorporates reengineering, modification and other activities with the goal of extending the useful life of the vehicle. Alternatively, an Inspect or Repair Only as Needed, or IROAN, is a much more limited program that only replaces components as required and does not feature reengineering or modification" (Hagan, 2009).

[4] "Average Procurement Unit Cost (APUC) is calculated by dividing total procurement cost by the number of articles to be procured" (Hagan, 2009, p. B-15).

## Author Biographies

**Mr. Ian D. MacLeod** is a senior national security analyst at the Johns Hopkins University–Applied Physics Lab. He previously worked for the Center for Naval Analyses supporting the U.S. Marine Corps at Marine Aviation Weapons and Tactics Squadron I; I and III Marine Expeditionary Forces; and the deputy commandant for Programs and Resources. He holds an MA in Applied Economics from the Johns Hopkins University, and a BA in Economics and International Relations from Syracuse University.

*(E-mail: ian.macleod@jhuapl.edu)*

**Capt Robert A. Dinwoodie, USMC**, has 14 years of business and active duty military experience. He currently is a regional manager for Expeditors International, designing corporate global supply chains. He previously served as a strategic investment analyst at Headquarters Marine Corps. Capt Dinwoodie earned an MS in Defense Systems Analysis Naval Postgraduate School (NPS); a BA from DePauw University in History; a Graduate Certificate in Cost Estimating & Analysis from NPS; and currently holds a Six Sigma Black Belt.

*(E-mail: robert.dinwoodie@outlook.com)*

# PROFESSIONAL READING LIST

The Defense Acquisition Professional Reading List is intended to enrich the knowledge and understanding of the civilian, military, contractor, and industrial workforce who participate in the entire defense acquisition enterprise. These book reviews/ recommendations are designed to complement the education and training that are vital to developing the essential competencies and skills required of the Defense Acquisition Workforce. Each issue of the *Defense Acquisition Research Journal (ARJ)* will contain one or more reviews of suggested books, with more available on the *Defense ARJ* Web site.

We encourage *Defense ARJ* readers to submit reviews of books they believe should be required reading for the defense acquisition professional. The reviews should be 400 words or fewer, describe the book and its major ideas, and explain its relevance to defense acquisition. Please send your reviews to the Managing Editor, *Defense Acquisition Research Journal*: *norene.fagan-blanch@dau.mil.*
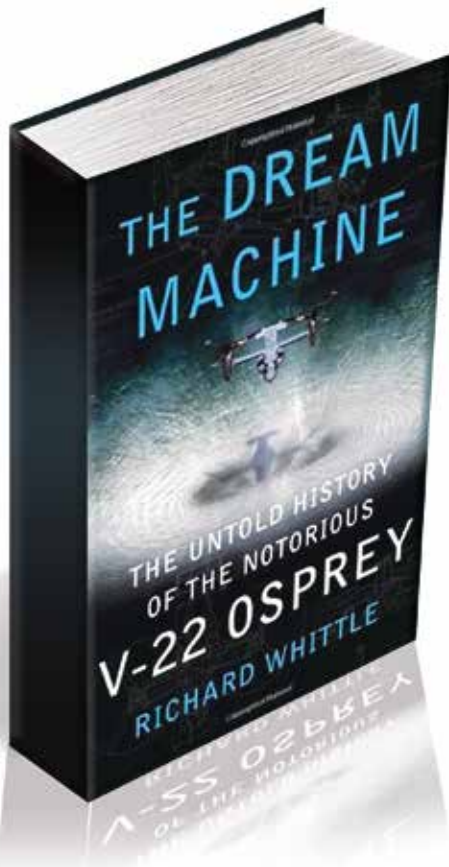
## Featured Book

*The Dream Machine: The Untold History of the Notorious V-22 Osprey*
**Author:**
Richard Whittle
**Publisher:**
Simon & Schuster
**Copyright Date:**
2010
**Hard/Softcover/Digital:**
Softcover, 456 pages, http:// www.amazon.com/The-Dream-Machine-History-Notorious/ dp/1416562966
**Reviewed by:**
Dr. Owen Gadeken, Professor of Acquisition Management, Defense Acquisition University
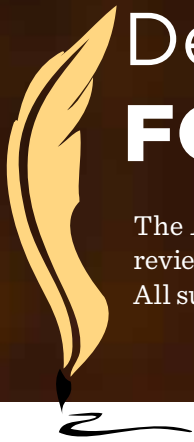
## Review:

Richard Whittle's *The Dream Machine* is as close to a comprehensive review of a defense acquisition program as we are likely to find in our current "sound byte"-focused culture. It traces the controversial and frequently maligned V-22 Osprey program from its earliest days to its vindication in 2011 after successful deployments to Iraq and Afghanistan. Whittle does this through the eyes of the key personalities in industry, government, and the U.S. Marine Corps who made the "dream" of tilt rotor technology into a reality with some of them giving their lives in the process.

One of the key figures profiled in the book is Richard "Dick" Spivey who started in 1959 as an 18-year-old Georgia Tech "co-op" student at Bell Helicopter in Fort Worth, Texas, worked his way up to "sales engineer" for the new tilt rotor, started a family, divorced, remarried, retired, came back as a consultant, and retired for good in 2006—all before the V-22 achieved its initial operational capability. During his tenure at Bell Helicopter, he traveled all over the world giving over 2,000 tilt rotor briefings and sales presentations.

The book is organized into 12 chapters, each one covering a specific facet of the V-22 story. For example, Chapter One "The Dream" traces the early attempts to develop a "convertiplane," which although unsuccessful, still offered the promise that such technologies could eventually be made to work. Chapter Two "The Salesman" uses Dick Spivey's career to illustrate the opportunistic, but persistent process used by defense contractors to market their products to the military. Chapter Three "The Customer" traces the convoluted requirements development and procurement processes used by the military to acquire the equipment they think they need. Chapter Four "The Sale" shows the extremely lengthy, but clever approach used by Bell and Boeing to market their immature tilt rotor technology into a systems contract with the Marine Corps. Other chapters detail the engineering trade-offs and political compromises made during development of the first V-22 prototypes. The author also provides detailed accounts of the major aircraft crashes that occurred as a result of tight funding, design compromises, and accelerated development, which drove the program in its early years.

The author's ability to integrate the key personalities that shaped the V-22 program into a chronological narrative that includes all major program events makes this not just a historical account, but a fascinating and insightful look at how dysfunctional our "military-industrial" complex has become. But with further reflection and analysis, the story of *The Dream Machine* can also help us find the way forward to construct an improved acquisition process, which will help us deliver our future dream machines.

# Defense ARJ Guidelines
# FOR CONTRIBUTORS

The *Defense Acquisition Research Journal (ARJ)* is a scholarly peer-reviewed journal published by the Defense Acquisition University (DAU). All submissions receive a blind review to ensure impartial evaluation.

## IN GENERAL

We welcome submissions from anyone involved in the defense acquisition process. *Defense acquisition* is defined as the conceptualization, initiation, design, development, testing, contracting, production, deployment, logistics support, modification, and disposal of weapons and other systems, supplies, or services needed for a nation's defense and security, or intended for use to support military missions.

*Research* involves the creation of new knowledge. This generally requires using material from primary sources, including program documents, policy papers, memoranda, surveys, interviews, etc. Articles are characterized by a systematic inquiry into a subject to discover/revise facts or theories with the possibility of influencing the development of acquisition policy and/or process.

We encourage prospective writers to coauthor, adding depth to manuscripts. It is recommended that a mentor be selected who has been previously published or has expertise in the manuscript's subject. Authors should be familiar with the style and format of previous *Defense ARJs* and adhere to the use of endnotes versus footnotes (refrain from using the electronic embedding of footnotes), formatting of reference lists, and the use of designated style guides. *It is also the responsibility of the corresponding author to furnish a government agency/employer clearance with each submission.*

# MANUSCRIPTS

Manuscripts should reflect research of empirically supported experience in one or more of the areas of acquisition discussed above. Empirical research findings are based on acquired knowledge and experience versus results founded on theory and belief. Critical characteristics of empirical research articles:

- clearly state the question,

- define the methodology,

- describe the research instrument,

- describe the limitations of the research,

- ensure results are quantitative and qualitative,

- determine if the study can be replicated, and

- discuss suggestions for future research (if applicable).

Research articles may be published either in print and online, or as a Web-only version. Articles that are 4,500 words or less (excluding abstracts, references, and endnotes) will be considered for print as well as Web publication. Articles between 4,500 and 10,000 words will be considered for Web-only publication, with an abstract (150 words or less) included in the print version of the *Defense ARJ*. In no case should article submissions exceed 10,000 words.

## Book Reviews

*Defense ARJ* readers are encouraged to submit reviews of books they believe should be required reading for the defense acquisition professional. The reviews should be 400 words or fewer describing the book and its major ideas, and explaining why it it relevant to defense acquisition. In general, book reviews should reflect specific in-depth knowledge and understanding that is uniquely applicable to the acquisition and life cycle of large complex defense systems and services.

## Audience and Writing Style

The readers of the *Defense ARJ* are primarily practitioners within the defense acquisition community. Authors should therefore strive to demonstrate, clearly and concisely, how their work affects this community. At the same time, do not take an overly scholarly approach in either content or language.

## Format

Please submit your manuscript with references in APA format (author-date-page number form of citation) as outlined in the *Publication Manual of the American Psychological Association* (6th Edition). For all other style questions, please refer to the *Chicago Manual of Style* (16th Edition).

Contributors are encouraged to seek the advice of a reference librarian in completing citation of government documents because standard formulas of citations may provide incomplete information in reference to government works. Helpful guidance is also available in *The Complete Guide to Citing Government Documents* (Revised Edition): *A Manual for Writers and Librarians* (Garner & Smith, 1993), Bethesda, MD: Congressional Information Service.

Pages should be double-spaced and organized in the following order: title page (titles, 12 words or less), abstract (150 words or less to conform with formatting and layout requirements of the publication), two-line summary, list of keywords (five words or less), body of the paper, reference list (only include works cited in the paper), author's note or acknowledgments (if applicable), and figures or tables (if any).

Figures or tables should not be inserted or embedded into the text, but segregated (one to a page) at the end of the text. When material is submitted electronically, *each figure or table should be saved to a separate, exportable file* (i.e., a readable EPS file). For additional information on the preparation of figures or tables, refer to the Scientific Illustration Committee, 1988,

*Illustrating Science: Standards for Publication*, Bethesda, MD: Council of Biology Editors, Inc. Restructure briefing charts and slides to look similar to those in previous issues of the *Defense ARJ*.

The author (or corresponding author in cases of multiple authors) *should attach a signed cover letter* to the manuscript that provides all of the authors' names, mailing and e-mail addresses, as well as telephone and fax numbers. The letter should verify that the submission is an original product of the author(s); that all the named authors materially contributed to the research and writing of the paper; that the submission has not been previously published in another journal (monographs and conference proceedings serve as exceptions to this policy and are eligible for consideration for publication in the *Defense ARJ*); and that it is not under consideration by another journal for publication. Details about the manuscript should also be included in the cover letter: for example, title, word length, a description of the computer application programs, and file names used on enclosed DVD/CDs, e-mail attachments, or other electronic media.

# COPYRIGHT

The *Defense ARJ* is a publication of the United States Government and as such is not copyrighted. Because the *Defense ARJ* is posted as a complete document on the DAU homepage, we will not accept copyrighted manuscripts that require special posting requirements or restrictions. If we do publish your copyrighted article, we will print only the usual caveats. The work of federal employees undertaken as part of their official duties is not subject to copyright except in rare cases.

Web-only publications will be held to the same high standards and scrutiny as articles that appear in the printed version of the journal and will be posted to the DAU Web site at www.dau.mil.

In citing the work of others, please be precise when following the author-date-page number format. It is the contributor's responsibility to obtain permission from a copyright holder if the proposed use exceeds the fair use provisions of the law (see U.S. Government Printing Office, 1994, *Circular 92: Copyright Law of the United States of America*, p. 15, Washington, D.C.). Contributors will be required to submit a copy of the writer's permission to the managing editor before publication.

We reserve the right to decline any article that fails to meet the following copyright requirements:

- The author cannot obtain permission to use previously copyrighted material (e.g., graphs or illustrations) in the article.

- The author will not allow DAU to post the article in our *Defense ARJ* issue on our Internet homepage.

- The author requires that usual copyright notices be posted with the article.

- To publish the article requires copyright payment by the DAU Press.

## SUBMISSION

All manuscript submissions should include the following:

- Cover letter

- Author checklist

- Biographical sketch for each author (70 words or less)

- Headshot for each author should be saved to a CD-R disk or e-mailed at 300 dpi (dots per inch) or as a high-print quality JPEG or Tiff file saved at no less than 5x7 with a plain background in business dress for men (shirt, tie, and jacket) and business appropriate attire for women. All active duty military should submit headshots in Class A uniforms. Please note: images from Web, Microsoft PowerPoint, or Word will not be accepted due to low image quality.

- One copy of the typed manuscript, including:

    ° Title (12 words or less)

    ° Abstract of article (150 words or less)

    ° Two-line summary

    ° Keywords (5 words or less)

   °   Document excluding abstract and references (4,500 words or less for the printed edition and 10,000 words or less for the online-only content)

These items should be sent electronically, as appropriately labeled files, to *Defense ARJ* Managing Editor: DefenseARJ@dau.mil.

# Defense ARJ
# PRINT SCHEDULE

The *Defense ARJ* is published in quarterly theme editions. All submissions are due by the first day of the month. See print schedule below.

| Author Deadline | Issue |
|---:|:---|
| July | January |
| November | April |
| January | July |
| April | October |

In most cases, the author will be notified that the submission has been received within 48 hours of its arrival. Following an initial review, submissions will be referred to peer reviewers and for subsequent consideration by the Executive Editor, *Defense ARJ*.

Contributors may direct their questions to the Managing Editor, *Defense ARJ*, at the address shown below, or by calling 703-805-3801 (fax: 703-805-2917), or via the Internet at norene.fagan-blanch@dau.mil.

The DAU Homepage can be accessed at:
*http://www.dau.mil*

DEPARTMENT OF DEFENSE

DEFENSE ACQUISITION UNIVERSITY

ATTN:  DAU PRESS (*Defense ARJ*)

9820 BELVOIR RD STE 3

FORT BELVOIR, VA 22060-5565

Defense Acquisition University

# WEB SITE
## http://www.dau.mil

*Your Online Access to Acquisition Research, Consulting, Information, and Course Offerings*



## Training

- Apply for Course
- Training Courses
- Continuous Learning Modules
- Certification Standards
- Targeted Training
- Student Policies & Mission Assistance
- Student Information System
- Training FAQs
- Request a Transcript

## Other Products

- Mission Assistance
- Knowledge Sharing
- Research Center
- DAU Knowledge Repository & Acker Archive
- Better Buying Power
- Life Cycle Chart
- iTunes
- *Defense Acquisition Guidebook*

## iCatalog

- Course Schedule
- Equivalency Fulfillment
- Predecessors/Prerequisites
- Schedules
- Course Material

## Publications

- *Defense AT&L Magazine*
- *Defense Acquisition Research Journal*
- DAU Brochures
- Archived Catalogs
- Annual Report
- Online Publications

# Now you can search the DAU Web site and our online publications!

# Defense Acquisition Research Journal
### S U R V E Y

**Please rate this publication based on the following scores:**

5 – Exceptional    4 – Great    3 – Good    2 – Fair    1 – Poor

1) How would you rate the overall publication? _____

2) How would you rate the design of the publication? _____

3) Please list all that apply: _____

| | True | False |
|---|---|---|
| a)  This publication is easy to read | | |
| b)  This publication is useful to my career | | |
| c)  This publication contributes to my job effectiveness | | |
| d)  I read most of this publication | | |
| e)  I recommend this publication to others in the acquisition field | | |

4) What themes or topics would you like to see covered in future *ARJs*? _____

_____

_____

5) What topics would you like to see get less coverage in future *ARJs*? _____

_____

_____

6)  How can we improve this publication?  Provide any constructive criticism to help us to improve this publication: _____

_____

_____

7) Please specify your organization: _____
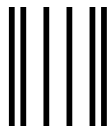
_____

_____

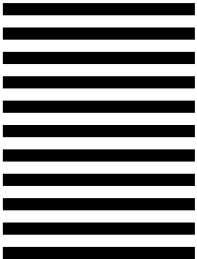# BUSINESS REPLY MAIL
FIRST-CLASS MAIL  PERMIT NO. 12  FORT BELVOIR,VA

POSTAGE WILL BE PAID BY ADDRESSEE

DEFENSE ACQUISITION UNIVERSITY
ATTN: DAU PRESS
9820 BELVOIR RD STE 3
FORT BELVOIR VA  22060-9910

# FREE ONLINE
SUBSCRIPTION

☐ *Defense ARJ*          *Defense AT&L* ☐

Thank you for your interest in *Defense AT&L* magazine and *Defense Acquisition Research Journal*. To receive your complimentary online subscription, please answer all questions below—incomplete forms cannot be processed.

**\*When registering, please do not include your rank, grade, service, or other personal identifiers.**

☐ *New Online Subscription*          ☐ *Cancellation*

☐ *Change of E-mail Address*

Date

Last Name:
First Name:
Day/Work Phone:

E-mail Address:

Signature: *(Required)*

PLEASE FAX TO: 703-805-2917

## The Privacy Act and Freedom of Information Act

In accordance with the Privacy Act and Freedom of Information Act, we will only contact you regarding your *Defense ARJ* and *Defense AT&L* subscription. If you provide us with your business e-mail address, you may become part of a mailing list we are required to provide to other agencies who request the lists as public information. If you prefer not to be part of these lists, please use your personal e-mail address.
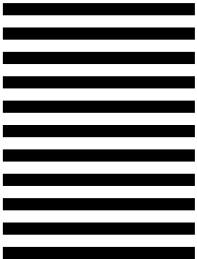
SUBSCRIPTION

# BUSINESS REPLY MAIL
FIRST-CLASS MAIL  PERMIT NO. 12  FORT BELVOIR,VA

POSTAGE WILL BE PAID BY ADDRESSEE

DEFENSE ACQUISITION UNIVERSITY
ATTN: DAU PRESS
9820 BELVOIR RD STE 3
FORT BELVOIR VA  22060-9910

# Defense Acquisition Research Journal

## A Publication of the Defense Acquisition University

**ARJ**

**Defense Acquisition Research Journal**

A Publication of the Defense Acquisition University

*Learn. Perform. Succeed.*

2015
**APEX**®
**AWARDS FOR PUBLICATION EXCELLENCE**